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System for Anomaly and Failure Detection (SAFD) System Development

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Volume I of V

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Task 233

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Executive Summary

Task assignment 233 is a continuation of Task 23 which specified developing a platform for executing the System for Anomaly and Failure Detection (SAFD) algorithm during hot fire tests at Technology Test Bed (TTB) and installing the SAFD algorithm on that platform. Two units were built and installed in the Hardware Simulation Lab and at the TTB in December 1991. Since that time, efforts have been toward improving and maintaining the systems, improving the algorithm, performing additional tests to prove the feasibility of the algorithm, and supporting hot fire testing. This document addresses the work done since the last report of January 1995 which closed Task 23.

The SAFD algorithm was developed to augment the current redline system used in the Space Shuttle Main Engine Controller (SSMEC). The primary goal was to save hardware during hot fire test failures. Execution against previous hot fire tests demonstrated that the SAFD algorithm can often detect engine failures prior to the redline system detecting them and, in some cases, this early detection could save significant hardware.

The algorithm operates continuously at 40ms intervals from start + 7.00 seconds to shutdown as long as the engine is in mainstage normal. It currently monitors 21 parameters and includes provisions for sensor qualification.

The algorithm uses simple equations to predict parameter values based on Pc Reference and inlet pressures. The limits are established around these predicted values. A five sample running average is maintained for each qualified parameter and is compared to the limits each cycle. The parameters are weighted for their contribution to cut and if the total weight of parameters out of limits exceeds the cut value, SAFD will request shutdown.

The algorithm includes two methods of sensor qualification; rate and range. The rate limit qualification disqualifies a parameters if the parameter moves more than the rate qualification limit in a 40 ms period. The range limits include an upper and lower limit for the parameter. The rate and range limits are set individually for each parameter.

All values for limits, delays, rates, weights, etc. are changeable by adaptation data.

The work on SAFD under Task 233 included improving the platform and the algorithm, deriving "standard" adaptation data, testing the algorithm against hot fire test data, providing support for operations at the TTB, providing routine maintenance, and moving the unit at TTB to SSC.

During this period, version 4.1 of the platform software was delivered. Version 4.0 of the algorithm was also formally delivered.

The changes to the platform software closed all but 5 of the outstanding System Problem Reports (SPRs). There are 4 outstanding SPRs against the platform and 1 against the algorithm. None of these problems are serious, but they should be corrected.

Under this task, efforts were initiated to derive "standard" adaptation data for the following engine configurations:

All Rocketdyne engine with nominal CCV schedule
Pratt LOX pump with nominal CCV schedule
Pratt LOX pump with modified CCV schedule

This standard adaptation data was derived with emphasis on reducing the risk of shutting down a good engine. Therefore, it can be expected to be less sensitive to failures.

This standard adaptation data was executed against 329 hot fire tests. These tests included the 33 failures designated "significant" by engine systems of which 19 were usable for SAFD testing, 29 "other" failures of which 24 were usable and 267 "good" tests of which 256 were usable. The unusable tests were either missing too much data or the engine shut down prior to SAFD activation.

As expected, the more generic adaptation data reduced algorithm sensitivity to failures. With engine specific and more sensitive data, 14 of the 19 usable significant failures were detected prior to redline shutdown. With the generic adaptation data, 8 of the 19 failures were detected prior to the redlines. The 5 cases originally detected that were not detected with the new adaptation data were rapid failures and engine systems determined that the early shutdowns indicated in earlier testing would not have saved hardware. There were 3 cases of early SAFD shutdown that engine systems determined would have saved hardware. These cases had a potential combined savings of over $40 million were detected early even with the new adaptation data (these were slowly occurring failures). The significant failure cases included two with Pratt LOX pumps.

The other failures group included 29 tests. Of the usable 24, SAFD indicated shutdown before the redlines in 4 tests.

The good tests group included 267 tests. Of these, 95 (88 usable) had a nominally Rocketdyne configured engine with nominal CCV schedule, 46 (45 usable) had a Pratt LOX pump with a nominal CCV schedule, and 126 (123 usable) had a Pratt LOX pump with a modified CCV schedule. SAFD indicated cut in only one of these tests (901-307) and the parameters appear to indicate off nominal engine operation. Further review is planned with engine systems to determine the cause of the shutdown on this test.

Under Task 233, Rocketdyne personnel supported SAFD during hot fire tests TTB-055 through TTB-059 except TTB-056. NASA personnel supported TTB-056. There was no unexpected behavior in these tests. SAFD was fully integrated into the TTB test process for tests TTB-057 through TTB-059 and the cutoff capability was activated for TTB-059. This activity was in preparation for moving the unit to SSC.

In December of 1995, the unit at TTB was moved to the A1 test stand at Stennis Space Center (SSC). After installation, SAFD personnel supported hot fire test 901-847 at SSC where SAFD operated in the monitor mode. The inputs for two of the facility parameters were reversed during this test, but no cutoff was signaled and the error was corrected post test. A post test rerun using the recorded data indicated no parameters out of limits. SAFD subsequently monitored test 901-848 with the only anomaly being that the PBP accel was disqualified due to loss of the signal.

Testing, both offline and at the test stands, indicates that the algorithm is acceptable for use on the test stands during nominal tests and that standard adaptation data can be used. However, the following conditions must be considered:

- The algorithm should not be used on tests where mixture ratio excursions, CCV excursions, or other special off-nominal tests are planned. If it is used during these tests, the limits must be expanded to accommodate the shifts in the parameter values or the adaptation data must be set to ignore the affected parameters.
- If the engine is a configuration other than those tested here, adaptation data changes will be required.
- The algorithm will cease monitoring during modes other than Mainstage Normal (eg. Thrust Limiting, Electrical Lockup, Hydraulic Lockup).

As a result of testing and analysis, several areas for improvement have been identified. These should be examined for feasibility and implemented if possible. These areas include further refinement of the adaptation data, use of dynamic data to establish all limits, and improvements in parameter prediction.

The algorithm is now being used at test stand A1 in monitor mode. Before it is activated for cut, a procedure should be established to include engine systems personnel in the process of generating/reviewing adaptation data.

This report concludes Task 233. All objectives of the task were met.

1 Introduction

TTB STA 23 specified building the hardware and software to implement the algorithm being developed under STA 21. The task involved building two units: one that is installed in the Hardware Simulation Lab (HSL) and one that was installed at the TTB. Task Assignment 233 specified moving the unit at TTB to Stennis Space Center (SSC) and that unit is currently installed at test stand A1. Rocketdyne personnel at the HSL performed the task. The effort since the last report has consisted of product improvement, testing, and maintenance.

1.1 Document Overview

This report relates in detail the approaches taken, the lessons learned, and recommendation for future efforts. The report is broken down as follows:

Section 1	Introduction
Section 2	The SAFD Platform
Section 3	The SAFD Algorithm
Section 4	Other Algorithms
Section 5	Summary

1.2 Deliverables

The following list enumerates the current documentation revision levels and serial numbers for deliverables.

Item	ID	Description
Doc	RHF-0032-001	System Specification
Doc	RHF-0032-005	System Development Plan
Doc	RHF-0032-007	User Guide
HW	SAFD serial # 1	SAFD Hardware
HW	SAFD serial # 2	SAFD Hardware
Doc	N/A	SAFD Hardware Drawings
SW	Platform v4.0	Platform Software
Doc	RHF-0032-003	Platform Software Requirements
Doc	RHF-0032-007	Platform Software Design
Doc	RHF-0032-011	Platform Test Plan
Doc	RHF-0032-013	Platform Test Description
Doc	RHF-0032-015	Platform Test Report
Doc		Platform Version Description Doc
SW	Algorithm v4.0	Algorithm Software
Doc	RHF-0032-020	Algorithm Software Requirements
Doc	RHF-0032-021	Algorithm Software Design
Doc	RHF-0032-022	Algorithm Test Plan
Doc	RHF-0032-023	Algorithm Test Description

Doc	RHF-0032-024	Algorithm Test Report
Doc		Algorithm Version Description Doc

1.3 Environment

SAFD is designed to operate in the SSME test stand environment. The system obtains Vehicle Data Table (VDT) input from a spare VDT output in the Command and Data Simulator (CADS), facility measurements from the facility Signal Interface Units (SIUs), and Greenwich Mean Time (GMT) from the facility GMT lines. It generates a cut signal by closing a relay connected to the facility cutoff panel. Figure 1 illustrates the configuration of SAFD at the TTB.

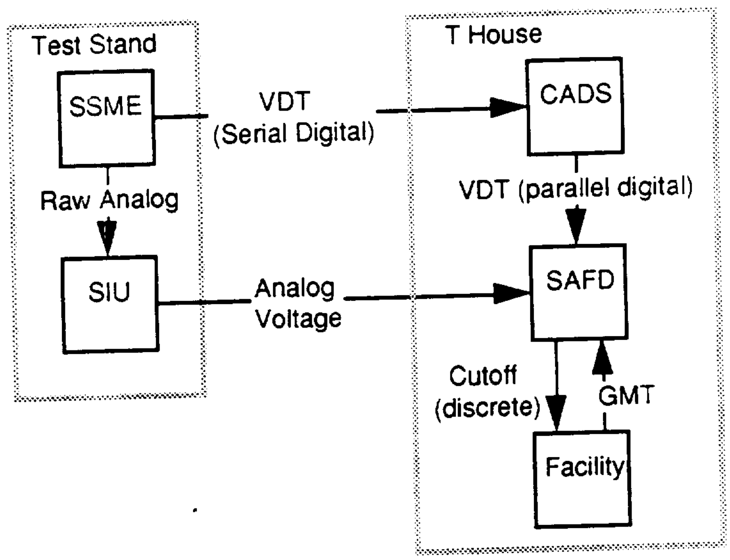

Figure 1 - SAFD TTB Configuration

1.4 System Overview

During the system definition phase, NASA and Rocketdyne agreed that it would be cost effective to separate the platform, which included the system hardware and those software functions not directly associated with the algorithm, from the algorithm implementation. The reasoning behind the decision was that the SAFD algorithm was being expanded to include transients and that at least two other efforts were underway to develop algorithms. This decision led to a system which allows multiple algorithms executing simultaneously and allows updating existing algorithms or creating new algorithms without modification of the platform software or hardware.

This modular approach led to a system where the platform handles all input/output, scaling, scheduling, recording/playback, display, and user interface as these functions are common to all algorithms. Isolating these function from the algorithms yields a stable platform upon which the algorithms can be executed. Since the algorithms do not contain generic functions, only the code directly required to implement a particular monitoring approach need be contained in the algorithm. The algorithms are thus isolated from the user and the hardware environment. Since the developer need not worry about the generic functions handled by the platform, it is easier to change existing algorithms and to create and integrate new algorithms. Figure 2 illustrates the concept.

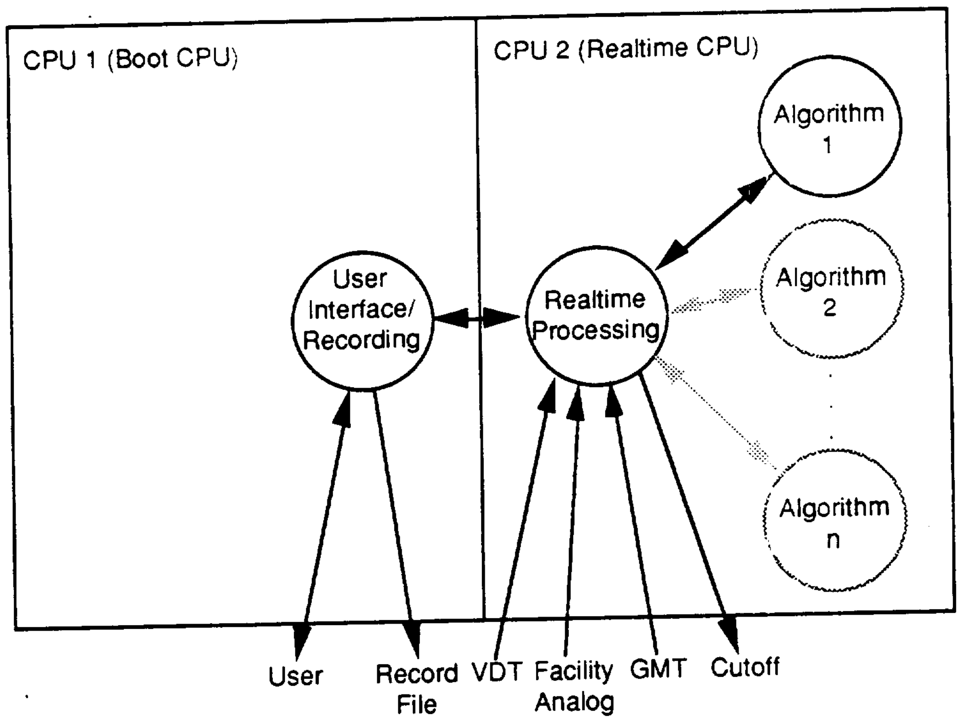

Figure 2 - SAFD System Architecture

2 SAFD Platform

The platform includes all hardware and software components except the algorithm software. Under Task Assignment 233 there were no significant modifications to the hardware, but a new version of the SAFD platform software was installed.

2.1 SAFD Platform Hardware

The SAFD platform hardware includes all hardware purchased or developed under the task. The hardware is built around a Concurrent 6450 computer using off-the-shelf components where available. Rocketdyne built custom hardware for those components not available off-the-shelf. Figure 3 shows a block diagram of the SAFD system.

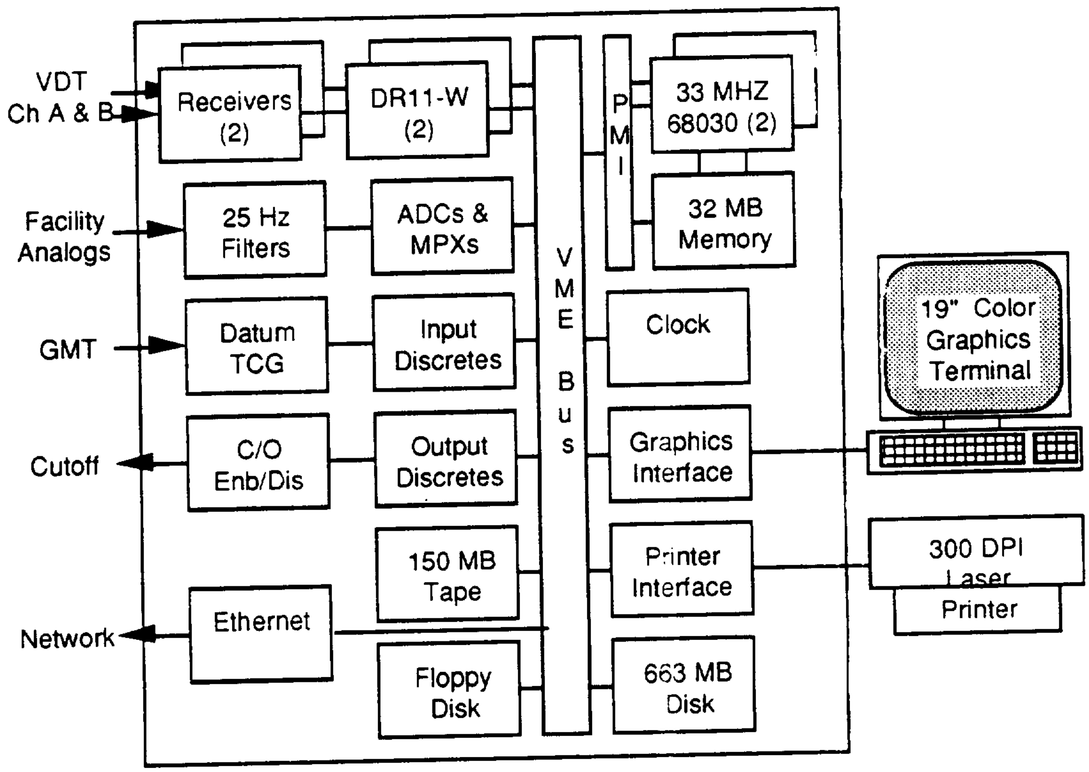

Figure 3 - SAFD Block Diagram

The major hardware components include the following:

Concurrent 6450 computer and peripherals
VDT interface
Facility analog interface
GMT Time Code Generator (TCG) and interface
Cutoff logic

2.1.1 SAFD Platform Hardware Changes

There were no platform hardware changes during this reporting period.

2.1.2 SAFD Platform Hardware Open SPRs

There are no SPRs open against the platform hardware.

2.2 SAFD Platform Software

The SAFD platform software includes all software not directly associated with an algorithm. Functions not requiring realtime response are executed on the boot processor (CPU1). Those requiring realtime response and the algorithms are executed on the realtime processor (CPU2). Figure 4 illustrates the software/hardware mapping for the system. The following paragraphs document changes in off-the-shelf vendor supplied software and in the Rocketdyne supplied software.

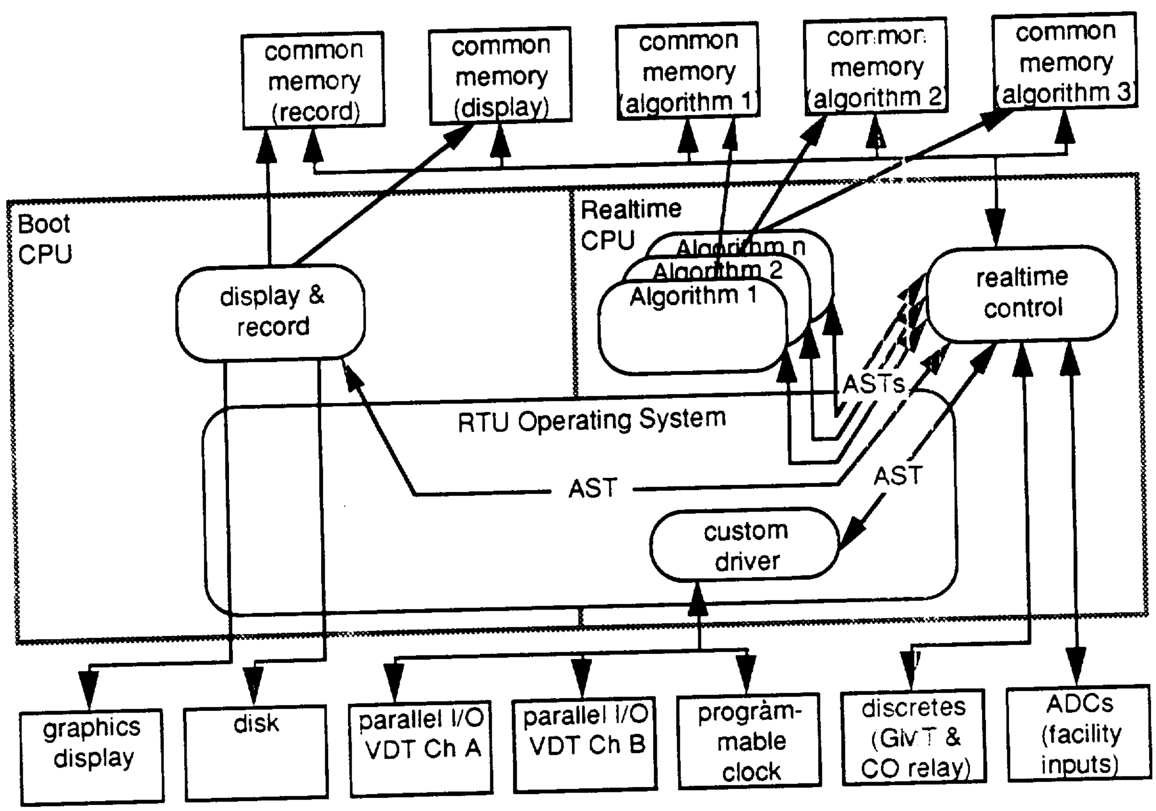

Figure 4 - Software / Hardware Mapping

2.2.1 SAFD Vendor Supplied Software

There were no changes in the vendor supplied software during this reporting period.

2.2.2 SAFD Rocketdyne Supplied Software

Version 4.1 of the Rocketdyne supplied platform software was installed in June 1995. Version 4.1 closed the following SPRs:

2924 No error msg displayed for syntax errors in algorithm map. This problem also exists in the parameter map.

2925 Algorithm and parameter maps do not allow comments.

2927 Playback cannot "back up" over an "out of synch" VDT.

2928 During test execution, platform hangs on "input not found" error condition.

2929 Platform allows only 9 facility parameters.

2930 Analyze function needs to be updated to modes and disqualification information available from new algorithm.

2931 Platform range checking is no longer needed.

2932 Make the test record file name available to user for use in graphs.

2933 Change "Save" and "Save As" to operate without requiring user to change something on the screen.

2934 Add the calibrated coefficients to the TRF and allow an ideal simulated calibration.

3476 Change cutoff checkout to allow the user to set and clear the cutoff relay.

2.2.3 SAFD Platform Software Open SPRs

The following SPRs remain open against the SAFD platform software.

2874 Test does not abort for loss of VDT.
The software will not abort a test when VDT data is lost. This is the preferred response as algorithms may someday exist which

do not require VDT data or there may be occasions where only facility data need be monitored (such as troubleshooting). The requirements will be changed in the next update.

2875 Data Errors not incremented for bad VDT.
The systems maintains the error count and marks "bad" VDTs, but does not post the count to the screen. This does not affect operation of the system.

2935 Occasionally calibration fails to input the correct low or high cal point because the cache does not get flushed.

3478 Platform hangs during test save if more than 128 parameters are entered in the parameter map.

3479 Platform allows user to save incomplete test setup.

2.3 Recommendations

SPR 2874 will be closed via requirements change. There are no plans to close SPR 2875 as the gain from implementing it does not justify the expense of implementation. SPRs 2935, 3478, and 3479 will be closed in the next release.

3 SAFD Algorithm

The requirements for the SAFD algorithm originated with the work done at Rocketdyne in Canoga Park, California under TTB Task 21. The SAFD algorithm was developed to augment the current redline system used in the Space Shuttle Main Engine Controller (SSMEC). Testing has demonstrated that with slowly occurring failures the SAFD algorithm can detect engine failures as much as tens of seconds before the redline system recognizes the failure.

3.1 Algorithm Version 4.0

Version 4.0 of the algorithm is currently installed in both units.

3.1.1 Algorithm Operation

The algorithm operates in 5 modes. In addition to the 5 modes, the algorithm implements a first instance check which simply verifies that the parameter is within a specified range during the first active cycle (7.00 or 7.02 seconds). Modes 1, 2, and 5 operate during steady state conditions. Modes 3 and 4 are active during power up and power down respectively. The requirements for cutoff have been changed such that any two turbine temperatures will cause a request for shutdown. Figure 5 illustrates algorithm operation Mode 4 operates as mode 3 but in the opposite direction. The algorithm also provides the capability to apply a gain to parameters during a specified time period and to modify parameter predictions based on inlet pressures and repress valve operation.

The algorithm includes qualification monitoring for both rate qualification and range qualification.

3.1.1.1 Shutdown Monitoring

Shutdown monitoring continues from 7.00 seconds after start until shutdown as long as the engine is in mainstage normal. If the engine enters other modes, such as thrust limiting or hydraulic or electrical lockup, monitoring is suspended. In order to request shutdown, the weights of the parameters out of limits must add up to 3.0. Currently, all parameters are weighted 1.0. A running average of the most recent 5 samples rather than the actual parameter value is checked against parameter limits for purposes of shutdown monitoring.

The algorithm maintains an expected value for each parameter. This expected value is used as a reference to establish the limits for each parameter.

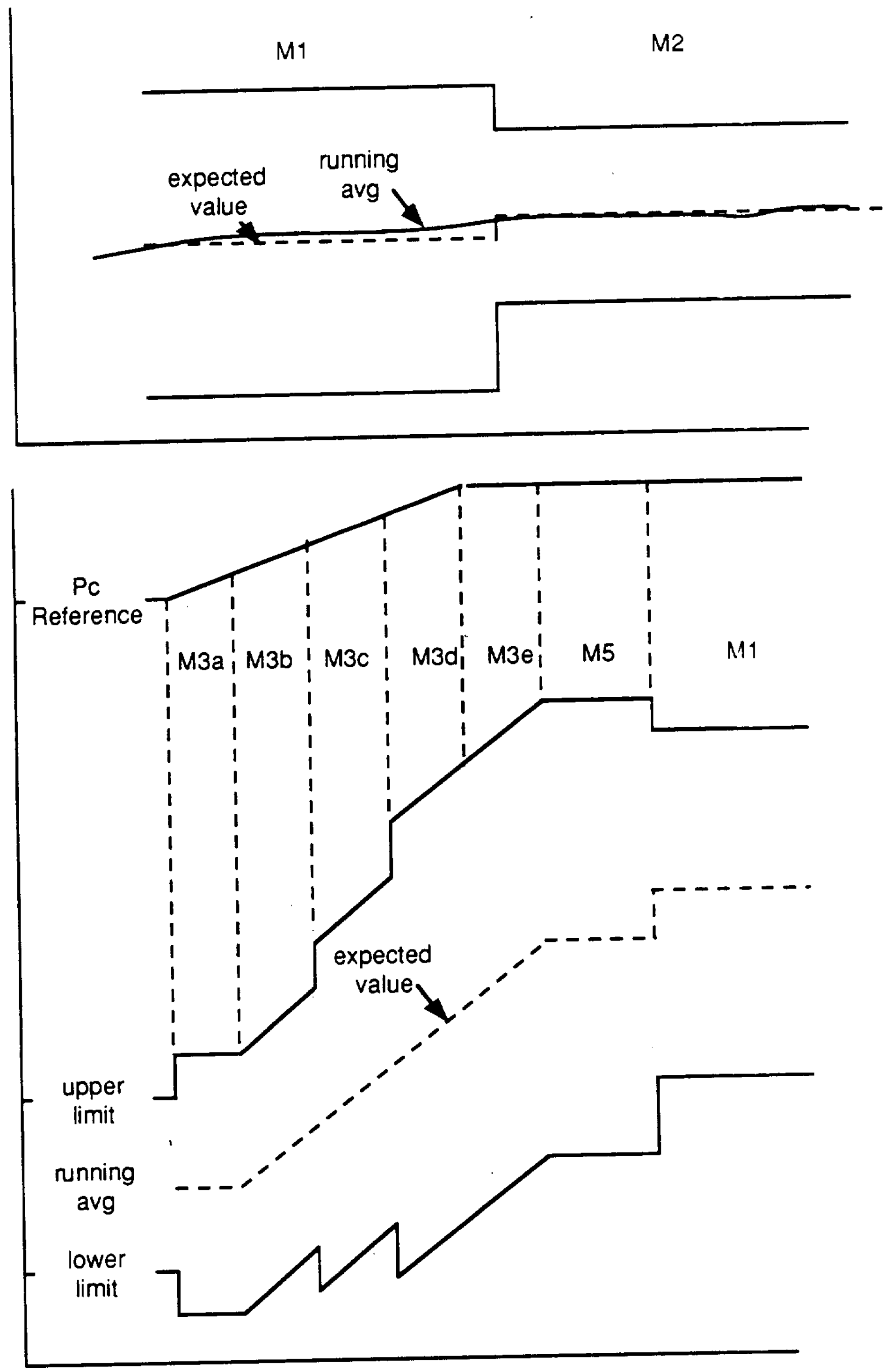

Figure 5 - Algorithm Operation

The algorithm adjusts the expected value of some parameters based on fuel and LOX inlet pressures. This is accomplished by adjusting the expected value of the parameter via a slope factor which is set via adaptation data and then reapplying the current limits based on the new expected value. Similarly, adjustments to certain parameters are made when the fuel and GOX repress valves are cycled except that the values are adjusted via an offset set by adaptation data.

The algorithm also provides the ability to modify the expected value as a function of time. This is accomplished by applying a gain during a specified interval with the gain and the interval being adaptation data. This allows closer prediction of parameters that drift over time such as HPOP IMSL Purge Pressure on engines with Rocketdyne LOX pumps.

At 7.00 seconds a first instance check is made. This check verifies that the parameter is within a preset range. The preset range is loaded via adaptation data. This first value begins the accumulation of values for use in calculating the 5 sample running average.

After the first instance check or at the conclusion of mode 5, the algorithm enters mode 1 and sets the expected value to the current running average. In this mode, the limits are based on a preset upper and lower band loaded as adaptation data. A value calculated by multiplying an n factor times a standard deviation is added to this upper and lower band. The n factor and standard deviation are loaded as adaptation data. The bands are then added (for the upper) and subtracted (for the lower) from the expected value to establish parameter limits. During this period values are saved to calculate standard deviation for use during mode 2. The length of time that the algorithm remains in mode 1 is determined by adaptation data and is nominally 2.00 seconds.

At the conclusion of mode 1, if the engine is in steady state, the algorithm enters mode 2 and sets the expected value to the current running average. Mode 2 uses preset upper and lower limits plus an n factor times the standard deviation calculated for mode 1. The preset upper and lower limits and the n factor are adaptation data. The resulting value is the added (for the upper) or subtracted (for the lower) from the expected value to establish the limits for mode 2. The algorithm will then remain in mode 2 until power level changes or until shutdown.

Modes 3 and 4 operate identically but in opposite directions. If the power level increases (as detected by monitoring Pc Reference), the algorithm will enter mode 3. If it decreases, the algorithm will enter mode 4. Note that all adaptation values for modes 3 and 4 are independent. Note also that modes 3 and 4 can be entered from any other mode.

Upon entry into mode 3 or 4, the algorithm sets the expected value to the current running average. It then sets the limits to this expected value plus (upper limit) and minus (lower limit) a preset upper and lower limit which are loaded via adaptation data. This submode (a) remains in effect for a preset period which is also set via adaptation data. This delay accommodates lag in the parameters with respect to changes in power level.

After expiration of the delay for submode a, the algorithm enters submode b, c, or d and begins to adjust the expected value of parameters based on a gain which is set via adaptation data. As the expected value changes, the limits are reapplied using the new expected value. The determination of which of these modes to enter is based on the amount of change in Pc Reference. The only difference in these submodes is the size of the bands for the parameter limits. Normally, the algorithm enters b, followed by c, followed by d, although it may skip one or more of these modes.

When Pc Reference levels off again, the algorithm enters submode e where it continues to use the limits established in the previous submode (a, b, c, or d) and adjusts the expected value via the gain (the same gain used for submodes b, c, and d). As it adjusts the expected value it also reapplies the limits. The algorithm remains in this mode for a period established via adaptation data. As with submode a, this accounts for lag in the parameter during changes in power level.

At the conclusion of submode e, the algorithm enters mode 5. In mode 5 it retains the previously set limits and the previously calculated expected value. It remains in mode 5 for a predetermined time set by adaptation data. At the conclusion of mode 5, the algorithm reenters mode 1 and begins the cycle anew.

3.1.1.2 Sensor Qualification

Sensor qualification was added to version 4.0 of the SAFD algorithm. The sensor qualification includes both range and rate qualification. All values used for sensor qualification are loaded as adaptation data.

The range qualification simply checks that the parameter is within a specified range.

The rate qualification calculates the amount of change in a parameter during each 40ms period and then compares this to the value loaded as adaptation data. This value is currently set at 60% of the sensor range for most of the parameters.

If a parameter fails either of these qualification tests, monitoring for that parameter is suspended for the duration of the test.

3.1.2 Algorithm Open SPRs

3477 Algorithm does not set output tags correctly under some conditions.

3.2 Off-Line Hot Fire Testing

In order to assess the validity of the algorithm, Rocketdyne personnel executed the algorithm against hot fire data. The data included cases with engine failures as well as good tests and included a variety of engines and engine configurations from all single engine test stands.

The parameter data from 329 tests were downloaded to the HSL. The tests were divided into three groups; significant failures, other failures, and good tests.

Since the last report an was initiated to "standardize" the adaptation data. Adaptation data was derived for the following engine configurations:

Rocketdyne pumps and nominal CCV schedule
Pratt LOX pump with nominal CCV schedule
Pratt LOX pump with modified CCV schedule

Gains for the parameter prediction equations were changed for each configuration. To get this data a sample of the gains during ramping was taken from 10 tests in that category and averaged.

In many cases, a statistical approach to deriving adapatation data for parameter limits did not yield the desired results. Instead an empirical approach was used where the adaptation data was executed against the good tests and, where a number of tests failed the same parameter and the parameter appeared normal, the limits were widened to accommodate the samples. The resulting adaptation data was then executed against the failure cases. The adaptation data was derived to minimize the chances of shutting down a good engine and therefore made the algorithm less sensitive to failures. The parameter limits for the configurations are the same for all configurations excepting HPOP IMSL Pr and HPFP Balance Cavity Pressure. These two are different for Rocketdyne and Pratt pump configurations.

Tables I, II, and III contain the adaptation data used for RD Engines w/ nominal CCV schedule, Pratt LOX pump w/ nominal CCV schedule and Pratt LOX pump w/ modified CCV schedule respectively.

The following paragraphs detail the results of these tests. Note that the results of this series of tests have not yet been reviewed by engine systems.

3.2.1 Significant Failures

A list of 33 significant failures obtained from engine systems constituted the "significant failures". Of the 33, 14 had no data, were shutdown during start, or had inadequate data. The results from the other 19 "significant failures" were analyzed and in 8 cases the SAFD algorithm detected the failure prior to shutdown. As expected, the standardized adaptation data reduced the sensitivity of the algorithm so that the percentage of failures detected was not as high as in previous testing. Previous reports indicated that 14 of the 19 failures were caught by SAFD prior to redline shutdown. The 5 that were no longer caught prior to shutdown were rapidly occurring failures and the earlier shutdowns would not have saved hardware. The 3 failures previously reported as potentially saving $40 million were still caught early with the generic adaptation data. Table IV contains a summary of the testing and Appendix A contains plots for the out of limit parameters.

All but two of the significant failure cases were executed using the adaptation data for Rocketdyne pumps and nominal CCV schedule. Two tests were engines with Pratt LOX pumps and the appropriate adaptation data was used for these tests.

750-041

Shutdown in Start.

750-148

SAFD did not detect the failure prior to shutdown. However, there were 7 of the 21 parameters missing or disqualified, including the HPOP TDTs. Note also that the failure occured during mode 1 while the limits on parameters are still quite wide. HPFP Balance Cavity Pr indicated out at 15.72 seconds and HPOP PBP Discharge Pr indicated out at 15.76. Engine shutdown was at 16.00 for HPOP TDT.

750-160

Shutdown in Start.

750-175

SAFD indicated cut at 115.60 for the following parameters:

- HPFP Balance Cavity Pr
- HPFP Coolant Liner Pr
- HPFP Discharge Pr
- HPOP Accel
- HPOP Discharge Pr
- HPOP PBP Discharge Pr
- LPOP Discharge Pr

Engine shutdown was after 115.60 for facility HPOP Accel.

750-259

SAFD indicated cut at 101.38 for the following parameters:

HPFP Coolant Liner Pr
HPFP Discharge Pr
HPFP TDT A
HPOP Discharge Pr
LPOP Discharge Pr
MCC Liner Cavity Pr

Engine shutdown was after 101.50 for facility HPFP Accel.

750-285

SAFD indicated no parameters out of limits. Engine shutdown was at 223.54 for powerhead thermocouple.

901-110
901-133
901-136
901-147

No data or bad data.

750-285

SAFD indicated no parameters out of limits.

Engine shutdown was at 223.54 for powerhead thermocouple.

901-173

SAFD did not detect the failure prior to shutdown. However, there were 7 of the 21 parameters missing or disqualified, including the HPFP TDTs. HPFP Coolant Liner Pr and MCC Pc indicated out of limits prior to shutdown with MCC Pc indicating out at 201.00 seconds and HPFP Coolant Liner Pr indicating out at 201.08.

Engine shutdown was after 201.16 for HPFP TDT.

901-183

SAFD did not detect the failure prior to shutdown. HPFP Balance Cavity Pr appeared ragged during the test and jumped high prior to shutdown. However, this was during a throttling phase where the limits were wider and the parameter did not register out of limits at this time. HPFP accel registered out of limits at 50.86 but three parameters are required for shutdown.

Engine shutdown was after 51.06 for HPFP Accel.

901-222

Data missing.

901-225

SAFD did not detect the failure prior to shutdown. HPOP TDT exceeded the upper limit at about 14 seconds and exhibited strange behavior at 117 seconds. HPOP IMSL Pr appears unusually high for the entire test and exceeded the limit at about 155 seconds. The two parameters may not be related to the shutdown.

Engine shutdown was after 255.58 for HPFP TDT. These TDTs appear OK in the VDT.

901-284

SAFD did not detect the failure prior to shutdown. However, the first instance check was not used for this run. It would have been able to detect the failure at 7.02 seconds. Engine systems estimates that $9.2 million could have been saved by early shutdown.

901-331

SAFD indicated cut at 232.48 for the following parameters:

HPFP Accel
HPFP Discharge Pr
LPFP Shaft Sp
MCC Pc

Engine shutdown was after 233.04 for HPOP Accel.

901-364

SAFD indicated cut at 386.20 for the following parameters:

HPFP Accel
HPFP TDT A
HPFP TDT B

The following parameters were lost at 268.52 seconds.

FPOV Pos
HPFP Discharge Pr
HPOP PBP Discharge Pr
HPOP TDT A
HPOP TDT B
LPFP Shaft Sp
LPOP Discharge Pr
OPOV Pos.

Engine shutdown was after 392.16 for HPOP Accel. Engine systems estimates that $24.5 million could have been saved by early shutdown.

901-436

SAFD indicated cut from 525.52 to 526.24 for the following parameters:

HPOP IMSL Pr
HPOP TDT A
HPOP TDT B

These do not appear related to the failure, but should be examined by engine systems.

SAFD indicates cut at 610.88 for the following parameters:

FPOV Position
Fuel Flow
HPFP Coolant Liner Pr
HPFP TDT A
HPFP TDT B

Engine shutdown was after 611.04 for HPFP TDT.

901-468

SAFD did not detect the failure. HPFP Coolant Liner Pr drops below the limit intermittently at 20 seconds but remains within limits thereafter.

Engine shutdown was after 203.88 for powerhead thermocouple.

901-666
902-120
902-132

Shutdown in Start.

902-198

SAFD did not detect the failure.

Engine shutdown was after 8.44 for HPOP Accel.

902-249

SAFD indicated cut at 378.54 for the following parameters:

HPFP Coolant Liner Pr
HPFP TDT A
HPFP TDT B

Engine shutdown was after 450.58 for HPFP Accel. Engine systems estimates that $14.5 million could have been saved by early shutdown.

902-428

SAFD indicated no parameters out of limits but the engine went into electrical lockup and SAFD only monitors mainstage normal.

Engine shutdown was after 204.00 by CADS for loss of HPFP TDT redline.

902-471

SAFD did not detect the failure. HPOP TDT B exceeded the lower limit intermittently from 82 to 139 seconds.

Engine shutdown was after 147.66 for powerhead thermocouple.

902-562

Shutdown in Start.

904-044 - Pratt LOX Pump

SAFD did not detect the failure prior to shutdown. At 1270.66 SAFD indicated HPFP Coolant Liner Pr and HPOP Discharge Pr out of limits.

Engine shutdown was after 1270.70 for MCC Pc.

904-145 - Pratt LOX Pump

SAFD indicated cut at 241.06 for the following parameters:

HPFP Discharge Pr
HPOP Discharge Pr
HPOP PBP Discharge Pr

Engine shutdown was after 241.10 for HPOP Accel.

3.2.2 Other Failures

The "other failures" group included 29 tests. Of these, 5 were missing too many parameters, were missing critical data items, or shut down in start. Of the remaining 24 other failures, SAFD indicated cut in 4 tests prior to shutdown. No analysis has been done to assess the results of these tests. Table V contains a summary of the testing and Appendix B contains plots for the out of limit parameters.

3.2.3 Good Tests

The "good tests" group included 268 tests. Of these, 95 were Rocketdyne only engines with nominal CCV scheduling, 47 had PW LOX pumps with nominal CCV scheduling, and 126 had PW LOX pumps with modified CCV scheduling. Only one "good" test resulted in a cut being signaled by

SAFD. This may actually be a bad test and will be reviewed with engine systems. The following paragraphs will attempt explanation of those tests with parameters indicating out of limits.

3.2.3.1 Rocketdyne Pumps and Nominal CCV

There were 95 tests with Rocketdyne HPOP and HPFP pumps and using the nominal CCV schedule. Seven terminated prior to SAFD activation or were missing too much data. There was one SAFD cut which appears valid and will be reviewed by engine systems. There were parameters out of limits on some of the tests. The tests having parameters out of limits are listed below with an explanation of the out of limits parameters. Table VI contains a summary of the testing and Appendix C1 contains plots for the out of limit parameters.

750-168

HPFP Balance Cavity Pr

Parameter drifts low and out of limits as though it's failing but then recovers. Since the algorithm had readjusted to the lower value during the throttling, the parameter goes out of limits when it recovers.

750-291

MCC Pc

Parameter spiked at the time of the power failure. May need to increase the limits although other tests with power failures don't seem to have the problem.

750-294

Pc Ref bad in data file. Test not valid for SAFD.

901-307 This test registered a cut. It is being investigated.

HPFP TDT A

Parameter shifts downward at about 20 seconds and again at about 60 seconds. The second shift causes it to go out of limits.

HPFP TDT B

Parameter continues decreasing even after throttling stopped. Eventually it exceeds the lower limit at about 50 seconds.

LPOP Discharge Pr

Parameter shifts downward and out of limits at about 17 seconds.

901-346

FPOV Pos

Parameter turns downward after throttle up and drops below lower limit. It then increases back to nominal. At about 375 seconds it again shifts downward and intermittently exceeds the lower limit.

LPFP Shaft Sp
Parameter shifts upward at about 300 seconds. At about 383 seconds a spike exceeds the upper limit.
MCC Liner Cavity Pr
Parameter drifts upward during test. On all other engines this parameter remains constant and below zero.

901-433
Most parameters disqualified because inlet pressures not available. Test not usable for SAFD evaluation.

901-579
Disqualified parameters
Disqualified due to LOX inlex pressure being disqualified.
Out of limit parameters
Out of limits due to shift in mixture ratio.

901-655
Disqualified parameters
Appears to be channel A failure.
HPFP Accel
Out of limits.

901-662
Not a problem. Pc Ref bad in data file after 75 seconds.

902-248
HPFP Coolant Liner Pr
Parameter drifts toward upper limit from 20 to 50 seconds. Intermittently out of limits for remainder of test.
HPOP IMSL Pr
Parameter levels off very early in test begins to climb again at about 300 seconds. This behavior differs from other Rocketdyne pumps.

902-587
HPFP Balance Cavity Pr
Parameter noisier than normal and drifts up between 75 and 165 seconds.

902-589
HPOP IMSL Pr
Parameter increases faster than expected and exceeds the uppper limit. It also levels off earlier than expected.

902-596

HPOP PBP Discharge Pr

Parameter noisy between 35 and 63 seconds. Spikes past lower limit for one cycle at 39 seconds.

3.2.3.2 Pratt LOX Pumps and Nominal CCV

There were 46 tests with a Rocketdyne HPFP and a Pratt HPOP and using the nominal CCV schedule. One test had bad data. Although there were no unexpected cuts, there were parameters out of limits on some of the tests. The tests having parameters out of limits are listed below with an explanation of the out of limits parameters. Table VII contains a summary of the testing and Appendix C2 contains plots for the out of limit parameters.

904-162

HPOP SSC Pr

Parameter behaves erratically from the beginning of the test.

904-165

HPOP SSC Pr

Parameter begins erratic behavior at about 240 seconds.

904-171

FPOV Pos

Parameter continues to climb after throttling at about 400 seconds.

904-172

FPOV Pos

Parameter drifts upward during test and finally exceeds upper limit at about 710 seconds. Returns to within limits at 784 seconds.

904-173

FPOV Pos

Parameter drifts upward during test and finally exceeds upper limit at about 701 seconds. It breaks the limit three additional times between 701 and 750 seconds.

904-174

HPOP SSC Pr

Parameter drifts upward faster than normal and exceeds the upper limit.

904-180

HPFP Accel

Parameter broke upper limit for one cycle at 371.16. Engine status was toggling between normal mainstage and thrust limiting.

3.2.3.3 Pratt LOX Pumps and Modified CCV

There were 126 tests with a Rocketdyne HPFP and a Pratt HPOP and using the modified CCV schedule. Three shutdown prior to SAFD activation. Although there were no unexpected cuts, there were parameters out of limits on some of the tests. The tests having parameters out of limits are listed below with an explanation of the out of limits parameters. Table VIII contains a summary of the testing and Appendix C3 contains plots for the out of limit parameters.

901-723

HPFP TDT A

Parameter drifts toward upper limit beginning at about 170 seconds and exceeds the upper limit at 245 and 251 seconds. It continues at the upper edge of the band for the remainder of the test.

HPOP IMSL A

Parameter climbs faster than normal at mainstage entry, then continues to rise and exceeds the upper limit at 112 seconds. It continues upward until about 180 seconds when it levels off. This pattern occurs in other Pratt LOX pumps but most settle out early and remain flat for the rest of the test. The phenomena is more pronounced in Rocketdyne LOX pumps.

MCC Pc

A spike exceeding the upper limit appears in the data at approximately 650 seconds. Data recording or post test data reduction problems are assumed to be the cause.

901-772

HPOP IMSL A

Parameter dips below lower limit between 341 and 386. This was a special test for HPOP ISML Pressure.

901-789

HPFP Accel

Parameter spikes over the upper limit at 509 seconds.

901-809

HPFP Accel

Parameter slowly drifts up until it exceeds the limit. It returns in limits when the engine is throttled at about 430 seconds.

901-816

HPFP Discharge Pr

Parameter continued toward upper limit after start and remained there until 125 seconds when it returned to normal.

HPOP TDT B

Parameter continued toward upper limit after start and intermittently exceeded the limit until throttling at 140 seconds. This has been seen in other Pratt LOX pumps and can be handled by adaptation data.

904-196

LPFP Shaft Sp

Parameter exhibits a downward spike at 363 seconds and exceeds the lower limit during the spike. The parameter spikes downward again at about 425 seconds and is disqualified. Instrumentation, data recording, or post test data reduction problems are assumed to be the cause. Hydraulic lockup occurred at 425 seconds.

904-201

HPFP TDT A

Parameter appears noisier than normal (compare to 901-723) and continues to drift upward until about 60 seconds. Spikes exceed the upper limit 6 times during the test with the longest duration being 160ms.

904-205

HPFP TDT A

Parameter appears noisier than normal (compare to 901-723). One spike exceeds the upper limit for 40 ms at 433 seconds. There is also an unexplained rise in the temperature at 170 seconds.

904-207

HPFP TDT A

Parameter drifts upward at 117 seconds and intermittently exceeds the upper limit between 187 and 423 seconds.

HPOP SSC Pr

Parameter drift accelerates upward at 95 seconds and parameter exceeds the upper limit until parameter levels off and limits "catch up" to it.

904-219

HPFP TDT A

Parameter begins to climb at 207 seconds exceeds the upper limit and returns to normal at 377 seconds.

904-220

HPFP TDT A

Parameter behaves same as in 904-219 from 117 to 377 seconds and again from 417 to 527 seconds.

904-227
HPFP Coolant Liner Pr
Parameter becomes erratic after 130 seconds and spikes above upper limit at 154 seconds. Test had IEA failure.

904-228
All Parameters
Anomalous behavior due to control stability test.

904-233
All Parameters
Anomalous behavior due to mixture ratio excursions.

904-234
HPFP TDT A
Parameter decreases after throttle at 10 seconds until about 55 seconds. This behavior has been noted on some engines with both Pratt pumps.
All Other Parameters
Anomalous behavior due to mixture ratio excursions.

904-235
HPFP TDT A
Parameter similar to that of 904-234. Intermittently breaks lower limit from 56 to 57 seconds. Hydraulic lockup occurred at 210 seconds.

904-236
HPFP TDT B
Parameter decreases from about 8 seconds until about 25 seconds. It drops below the lower limit between 21 and 37 seconds. An unexplained increase in temperature occurs at about 130 seconds.

904-242
HPFP TDT B
Parameter is very erratic for entire test.

904-243
HPFP TDT B
Parameter is very erratic during early part of test and generally declines from 15 seconds until throttle at 35 seconds. Breaks the lower limit for about 1/2 second at 35 seconds.

904-244

HPOP PBP Discharge Pr

A spike exceeding the upper limit appears in the data at approximately 645 seconds. Instrumentation, data recording, or data reduction problems are assumed to be the cause.

904-246

HPFP TDT B

Behavior similar to 904-243. Parameter dips between 15 seconds and 22 seconds. Breaks the lower limit for about 1/2 second at 36 seconds.

3.3 Simulation Lab Testing

No additional tests were run in the HSL during this reporting period.

3.4 Live Hot Fire Test Experience

In January 1995, the new algorithm was installed at the TTB and monitored tests TTB-054 through 059. The SAFD cutoff was active for test TTB-059. In December 1995 the unit was moved to A1 at SSC where it monitored tests 901-847 and 901-848.

3.4.1 TTB Testing

TTB-054 - There were no anomalies noted for this test.

TTB-055 - Dynamic CCV rescheduling was used during this test. Since the SAFD adaptation data was not modified to accommodate this, some parameters indicated out of limits.

TTB-056 - Rocketdyne did not support this test.

TTB-057 - SAFD personnel began working directly with TTB personnel to derive limits and gains for the parameters. An erroneous entry in the parameter map file resulted in the wrong scaling coefficients being used for HPOP SSC Pr which caused it to be disqualified. There were no other anomalies.

TTB-058 - There were no anomalies noted for this test. This test included both mixture ratio and CCV excursions, but the SAFD adaptation data was modified to accommodate the off nominal conditions.

TTB-059 - There were no anomalies noted for this test. SAFD cutoff was active for this test.

3.4.1 A1 Testing

901-847 - Two facility parameters (HPFP Bal. Cav. Pr and PBP Accel) were reversed in the parameter map causing them to indicate out of limits during the test. After correcting the file the test was rerun in simulate mode and no anomalies noted. Appendix D1 contains the plots for the rerun of this test.

901-848 - During the test the PBP accel signal was lost and the accel was disqualified. No other anomalies were noted. Appendix D2 contains the plots for this test.

3.5 Algorithm Analysis

In examining the theory behind the algorithm, the idea of using standard deviation for determining limits in modes 1 and 2 but not in modes 3, 4, and 5 seems logically inconsistent. The reasoning originally professed for using standard deviation was to accommodate differences in sensor noise among engines and tests. This argument should apply to modes 3, 4, and 5 if it is appropriate for modes 1 and 2.

Even with the ability to change a parameter based on time, HPOP ISML Pr still presents a problem, particularly for Rocketdyne pumps. The limits have been expanded to accommodate this but this affects algorithm sensitivity.

The original requirements specified using 60% of the range of a sensor for rate qualification. Testing indicates that this rule of thumb does not always apply and the range qualification limit for some parameters have been changed. The range values for all parameters should be reevaluated with engine systems.

3.6 Conclusions

Testing indicates that version 4.0 of the algorithm represents a significant improvement over previous versions. The new algorithm is less sensitive to changes in adaptation data and using "standardized" adaptation data is feasible. Testing indicates that the algorithm is suitable for test stand use but there are areas that can be improved. Areas for improvement include the adaptation data, sensor qualification, the method for determining limits in modes 3, 4, and 5, and the equations for predicting parameter values.

The "standard" adaptation data used for this testing can be improved. For example, HPOP IMSL Pr needs further work. Besides improving the existing adaptation data, additional "standard" data should be developed to handle off nominal operation such as electrical or hydraulic lockup, mixture ratio changes, etc. as well as for other engine configurations, such as Block II engines.

Sensor qualification can also be improved. The sensor qualification does not completely guard against failures in the engine controller which can affect parameters, such as IE disqualification. Since some of the parameters are a single sensor rather than an average of qualified sensors, the SAFD algorithm can attempt to use the sensor values while the controller is in the process of disqualifying them. In addition to this potential problem, the 60% value used to rate qualify sensors does not appear to be the optimum for all parameters. Some have been changed based on test experience, but all should be evaluated to determine the best value. Note, however, that using the 5 sample running average and requiring multiple parameters out of limits for shutdown reduce the risk of erroneous shutdown due to failed sensors.

Although not confirmed by testing, analysis suggests that the logic that suggests using the standard deviation to modify the limits during modes 1 and 2 can be applied to modes 3, 4, and 5. This would make the limits calculated during these modes more logically consistent with those of modes 1 and 2. If the assumption is that this additional expansion of the limits for modes 1 and 2 accommodates parameter or sensor noise, then the same argument can be used for the other modes.

The equations used to derive the expected value for parameters do not always accurately reflect the behavior of the parameter. This is particularly apparent during throttling for some parameters. Since there is no provision for delay at the end of a throttle based on distance throttled, a compromise between the delay for a short throttle and the delay for a long throttle must be made. A more sophisticated method for deriving the expected values would improve algorithm reliability and make derivation of adaptation data easier.

The current algorithm appears adequate for test stand use and generating standardized adaptation data for specific engine configurations appears feasible. The improvements indicated are not necessary to use the algorithm but would make it more robust and easier to use.

3.7 Recommendations

While the algorithm is adequate for test stand use, the areas for improvement listed above should be addressed as budget permits. Additionally, some formal procedure should be established to include engine systems personnel in the process of generating adaptation data.

4 Other Algorithms

No algorithms other than SAFD were tested during this period.

5 Summary

Overall, the SAFD platform and algorithm performed well. The SAFD algorithm is acceptable for use on single engine stands monitoring production engines. Before using the current algorithm the following conditions must be considered:

- The algorithm should not be used on tests where mixture ratio excursions, CCV excursions, or other special off-nominal tests are planned. If it is used during these tests, the limits must be expanded to accommodate the shifts in the parameter values.
- If the engine is a configuration other than those tested here, adaptation data changes will be required.
- The algorithm will cease monitoring during modes other than Mainstage Normal (eg. Thrust Limiting, Electrical Lockup, Hydraulic Lockup).

Testing has proven valuable in assessing the strengths and weaknesses of the SAFD algorithm. Testing also identified several potential areas for improvement for the algorithm. Development on the algorithm should continue in order to address these areas of improvement.

Additional testing and analysis should be done to gain a better understanding of what parameters can provide indications of impending engine failure and what those indications are. NASA and Rocketdyne Engine Systems personnel should assist in evaluating the results of the testing and analysis.

In addition to testing and analyzing the SAFD algorithm, other available algorithms should be examined to determine whether ideas from several of the algorithms could be integrated to produce a superior solution.

Finally, before the algorithm is activated on a test stand, a formal procedure should be established that includes engine systems in the process of dfining the adaptation data.

6 Acronyms

ATD	Advanced Turbopump Design
DCU	Digital Computer Unit
CADS	Command And Data Simulator
CPU	Computer Processing Unit
FPOV	Fuel Preburner Oxidizer Valve
FY	Fiscal Year
GMT	Greenwich Mean Time
GOX	Gaseous Oxygen
HEX	Heat Exchanger
HPFTP	High Pressure Fuel Turbopump
HPOTP	High Pressure Oxidizer Turbopump
HSL	Hardware Simulation Laboratory
IE	Input Electronics
ISP	Intermediate Seal Purge
I/O	Input/Output
LeRC	Lewis Research Center
LOX	Liquid Oxygen
LPFTP	Low Pressure Fuel Turbopump
LPOTP	Low Pressure Oxidizer Turbopump
MB	Megabyte
MCC Pc	Main Combustion Chamber Chamber Pressure
MHz	Megahertz
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
OE	Output Electronics
OPOV	Oxidizer Preburner Oxidizer Valve
PBP	Preburner Pump
PID	Parameter Identifier
SAFD	System for Anomaly and Failure Detection
SIU	Signal Interface Unit
SPR	System Problem Report
SSC	Secondary Seal Cavity
SSME	Space Shuttle Main Engine
SSMEC	Space Shuttle Main Engine
STA	Special Task Assignment
TCG	Time Code Generator
TDT	Turbine Discharge Temperature
TTB	Technology Test Bed
UTRC	United Technologies Research Center
VDT	Vehicle Data Table

Table I

Adaptation Data for Rocketdyne Pumps w/ Nominal CCV Schedule

```
/* adaptation data using 10 samples from 750, 901, 902 RDB NC for gains
      for RD engines w/ nominal CCV schedule */

COLIMIT 3      /* data for safd_4 algorithm */
RPL 3006.0     /* pcref at 100% */
GOXVALVE
      CLOSE          500.0  /* <time>*/

FUELVALVE
      CLOSE          500.0 /* <time>*/

LPOP_INLET_PR
      QUL            200.0
      QLL            0.0
      QRATE          120.0

LPFP_INLET_PR
      QUL            100.0
      QLL            0.0
      QRATE          60.0
```

```
PARAM FPOV_POS   norm   CUTWEIGHT 1

        QUL                 105.0
        QLL                 0.0
        QRATE               20.0
        MODE1DWELL          2.0
        MODE3ADWELL         0
        MODE3EDWELL         .24
        MODE4ADWELL         0
        MODE4EDWELL         0
        MODE5DWELL          1.0
        MODE3CPCDELTA       100.0
        MODE3DPCDELTA       101.0
        MODE4CPCDELTA       100.0
        MODE4DPCDELTA       101.0

        CHN
              SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
              LOXGAIN       0.01
              FUELGAIN      -.02
              LOXOFFST      0
              FUELOFFST     0
              TIMEGAIN      0
              TIMESTART     0
              TIMESTOP      0
              MODE0UL       105.0
              MODE0LL       0.0
              MODE1UL       1.4
              MODE1LL       1.4
              MODE1SD       1.4
              MODE1FACT     3.0
              MODE2UL       2.0
              MODE2LL       2.0
              MODE2FACT     3.0
              MODE3GAIN     3.40
              MODE3S1UL     6.5
              MODE3S1LL     6.5
              MODE3S2UL     6.5
              MODE3S2LL     6.5
              MODE3S3UL     6.5
              MODE3S3LL     6.5
              MODE4GAIN     -3.06
              MODE4S1UL     6.5
              MODE4S1LL     6.5
              MODE4S2UL     6.5
              MODE4S2LL     6.5
              MODE4S3UL     6.5
              MODE4S3LL     6.5
```

```
PARAM FUEL_FLOW  norm  CUTWEIGHT 1

        QUL              24000
        QLL              0
        QRATE            14400
        MODE1DWELL       2.0
        MODE3ADWELL      0.28
        MODE3EDWELL      0.12
        MODE4ADWELL      0.28
        MODE4EDWELL      0.12
        MODE5DWELL       0.2
        MODE3CPCDELTA    11.0
        MODE3DPCDELTA    101.0
        MODE4CPCDELTA    11.0
        MODE4DPCDELTA    101.0

        CHN
              SAMPLEWTS  0.05  0.05  0.1  0.2  0.6
              LOXGAIN    0
              FUELGAIN   -2.1
              LOXOFFST   0
              FUELOFFST  0
              TIMEGAIN   0
              TIMESTART  0
              TIMESTOP   0
              MODE0UL    24000
              MODE0LL    0
              MODE1UL    250
              MODE1LL    250
              MODE1SD    250
              MODE1FACT  3.0
              MODE2UL    350
              MODE2LL    350
              MODE2FACT  3.0
              MODE3GAIN  1551
              MODE3S1UL  1000
              MODE3S1LL  1000
              MODE3S2UL  1000
              MODE3S2LL  1000
              MODE3S3UL  1000
              MODE3S3LL  1000
              MODE4GAIN  -1575
              MODE4S1UL  1000
              MODE4S1LL  1000
              MODE4S2UL  1000
              MODE4S2LL  1000
              MODE4S3UL  1000
              MODE4S3LL  1000
```

```
/*PARAM      HEX_BYPASS_MIX_INTERFACE_TEMP  norm  CUTWEIGHT 1

        QUL               500
        QLL               -300
        QRATE             480
        MODE1DWELL        2.0
        MODE3ADWELL       0.24
        MODE3EDWELL       0.24
        MODE4ADWELL       0.24
        MODE4EDWELL       0.24
        MODE5DWELL        0.2
        MODE3CPCDELTA     100.0
        MODE3DPCDELTA     101.0
        MODE4CPCDELTA     100.0
        MODE4DPCDELTA     101.0

        CHN
              SAMPLEWTS   0.05  0.05  0.1   0.2   0.6
              LOXGAIN     -1.0
              FUELGAIN    0
              LOXOFFST    0
              FUELOFFST   0
              TIMEGAIN    0
              TIMESTART   0
              TIMESTOP    0
              MODE0UL     500
              MODE0LL     -300
              MODE1UL     40.0
              MODE1LL     50.0
              MODE1SD     0
              MODE1FACT   3.0
              MODE2UL     40.0
              MODE2LL     50.0
              MODE2FACT   3.0
              MODE3GAIN   0
              MODE3S1UL   0
              MODE3S1LL   0
              MODE3S2UL   0
              MODE3S2LL   0
              MODE3S3UL   0
              MODE3S3LL   0
              MODE4GAIN   0
              MODE4S1UL   0
              MODE4S1LL   0
              MODE4S2UL   0
              MODE4S2LL   0
              MODE4S3UL   0
              MODE4S3LL   0
```

```
*/
/*PARAM      HEX_VENTURI_DELTA_PRESSURE  norm CUTWEIGHT 1

      QUL                 500
      QLL                 -500
      QRATE               600
      MODE1DWELL          2.0
      MODE3ADWELL         0.24
      MODE3EDWELL         0.24
      MODE4ADWELL         0.24
      MODE4EDWELL         0.24
      MODE5DWELL          0.2
      MODE3CPCDELTA       100.0
      MODE3DPCDELTA       101.0
      MODE4CPCDELTA       100.0
      MODE4DPCDELTA       101.0
      .
      CHN
            SAMPLEWTS     0.05  0.05  0.1   0.2   0.6
            LOXGAIN       -0.07
            FUELGAIN      0
            LOXOFFST      0
            FUELOFFST     0
            TIMEGAIN      0
            TIMESTART     0
            TIMESTOP      0
            MODE0UL       500.0
            MODE0LL       -500.0
            MODE1UL       5.0
            MODE1LL       5.0
            MODE1SD       0
            MODE1FACT     3.0
            MODE2UL       5.0
            MODE2LL       5.0
            MODE2FACT     3.0
            MODE3GAIN     0
            MODE3S1UL     0
            MODE3S1LL     0
            MODE3S2UL     0
            MODE3S2LL     0
            MODE3S3UL     0
            MODE3S3LL     0
            MODE4GAIN     0
            MODE4S1UL     0
            MODE4S1LL     0
            MODE4S2UL     0
            MODE4S2LL     0
            MODE4S3UL     0
            MODE4S3LL     0
```

```
*/
PARAM        HPFTP_ACCEL  type2  CUTWEIGHT 1

    QUL                  30
    QLL                  0
    QRATE                18
    MODE1DWELL           2.0
    MODE3ADWELL          0.24
    MODE3EDWELL          0.24
    MODE4ADWELL          0.24
    MODE4EDWELL          0.24
    MODE5DWELL           0.2
    MODE3CPCDELTA        100.0
    MODE3DPCDELTA        101.0
    MODE4CPCDELTA        100.0
    MODE4DPCDELTA        100.0

    CHN
          SAMPLEWTS      0.05  0.05  0.1   0.2   0.6
          LOXGAIN        0
          FUELGAIN       0
          LOXOFFST       0
          FUELOFFST      0
          PCREFLMTS      65    8.0   0
                         90    8.5   0
                         100   9.0   0
                         104   9.5   0
                         109   10.0  0
                         111   10.0  0
```

```
PARAM HPFTP_BALANCE_CAVITY_PRESSURE  norm CUTWEIGHT 1

        QUL                     10000
        QLL                     0
        QRATE                   4000
        MODE1DWELL              2.0
        MODE3ADWELL             0.28
        MODE3EDWELL             0.48
        MODE4ADWELL             0.28
        MODE4EDWELL             0.24
        MODE5DWELL              1.0
        MODE3CPCDELTA           10.0
        MODE3DPCDELTA           11.0
        MODE4CPCDELTA           10.0
        MODE4DPCDELTA           11.0

        CHN
                SAMPLEWTS       0.05   0.05   0.1    0.2    0.6
                LOXGAIN         0
                FUELGAIN        0
                LOXOFFST        0
                FUELOFFST       0
                TIMEGAIN        0
                TIMESTART       0
                TIMESTOP        0
                MODE0UL         10000.0
                MODE0LL         0
                MODE1UL         100
                MODE1LL         100
                MODE1SD         50
                MODE1FACT       3.0
                MODE2UL         100
                MODE2LL         100
                MODE2FACT       3.0
                MODE3GAIN       425
                MODE3S1UL       400
                MODE3S1LL       400
                MODE3S2UL       400
                MODE3S2LL       400
                MODE3S3UL       400
                MODE3S3LL       400
                MODE4GAIN       -424
                MODE4S1UL       400
                MODE4S1LL       400
                MODE4S2UL       400
                MODE4S2LL       400
                MODE4S3UL       400
                MODE4S3LL       400
```

```
PARAM HPFTP_COOLANT_LINER_PRESSURE  norm  CUTWEIGHT 1

    QUL                     7000
    QLL                     1800
    QRATE                   4200
    MODE1DWELL              2.0
    MODE3ADWELL             0.24
    MODE3EDWELL             0.48
    MODE4ADWELL             0.24
    MODE4EDWELL             0.24
    MODE5DWELL              1.0
    MODE3CPCDELTA           11.0
    MODE3DPCDELTA           26.0
    MODE4CPCDELTA           11.0
    MODE4DPCDELTA           26.0

    CHN
            SAMPLEWTS       0.05   0.05   0.1    0.2    0.6
            LOXGAIN         0
            FUELGAIN        0
            LOXOFFST        0
            FUELOFFST       0
            TIMEGAIN        0
            TIMESTART       0
            TIMESTOP        0
            MODE0UL         7000
            MODE0LL         1800
            MODE1UL         75
            MODE1LL         75
            MODE1SD         75
            MODE1FACT       3.0
            MODE2UL         60
            MODE2LL         60
            MODE2FACT       3.0
            MODE3GAIN       333
            MODE3S1UL       95
            MODE3S1LL       500
            MODE3S2UL       500
            MODE3S2LL       500
            MODE3S3UL       500
            MODE3S3LL       500
            MODE4GAIN       -344
            MODE4S1UL       500
            MODE4S1LL       500
            MODE4S2UL       500
            MODE4S2LL       500
            MODE4S3UL       500
            MODE4S3LL       500
```

```
PARAM HPFTP_DISCHARGE_PRESSURE  norm  CUTWEIGHT 1

    QUL                 9500
    QLL                 0
    QRATE               5700
    MODE1DWELL          2.0
    MODE3ADWELL         0.28
    MODE3EDWELL         0.36
    MODE4ADWELL         0.36
    MODE4EDWELL         0.24
    MODE5DWELL          1.0
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
          LOXGAIN       -0.25
          FUELGAIN      -0.2
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       9500
          MODE0LL       0
          MODE1UL       150
          MODE1LL       150
          MODE1SD       150
          MODE1FACT     3.0
          MODE2UL       80
          MODE2LL       80
          MODE2FACT     3.0
          MODE3GAIN     608
          MODE3S1UL     850
          MODE3S1LL     850
          MODE3S2UL     850
          MODE3S2LL     850
          MODE3S3UL     850
          MODE3S3LL     850
          MODE4GAIN     -611
          MODE4S1UL     850
          MODE4S1LL     850
          MODE4S2UL     850
          MODE4S2LL     850
          MODE4S3UL     850
          MODE4S3LL     850
```

```
PARAM HPFTP_SHAFT_SPEED norm  CUTWEIGHT 1

        QUL                   45000
        QLL                   0
        QRATE                 27000
        MODE1DWELL            2.0
        MODE3ADWELL           0.24
        MODE3EDWELL           0.24
        MODE4ADWELL           0.24
        MODE4EDWELL           0.24
        MODE5DWELL            1.0
        MODE3CPCDELTA         100.0
        MODE3DPCDELTA         101.0
        MODE4CPCDELTA         100.0
        MODE4DPCDELTA         101.0

        CHN
                SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
                LOXGAIN       0
                FUELGAIN      -4.9
                LOXOFFST      0
                FUELOFFST     0
                TIMEGAIN      0
                TIMESTART     0
                TIMESTOP      0
                MODE0UL       45000
                MODE0LL       0
                MODE1UL       400
                MODE1LL       400
                MODE1SD       400
                MODE1FACT     3.0
                MODE2UL       300
                MODE2LL       300
                MODE2FACT     3.0
                MODE3GAIN     2050
                MODE3S1UL     2500
                MODE3S1LL     2500
                MODE3S2UL     2500
                MODE3S2LL     2500
                MODE3S3UL     2500
                MODE3S3LL     2500
                MODE4GAIN     -2048
                MODE4S1UL     2500
                MODE4S1LL     2500
                MODE4S2UL     2500
                MODE4S2LL     2500
                MODE4S3UL     2500
                MODE4S3LL     2500
```

```
PARAM HPFTP_TURBINE_DIS_TEMP_CH_A  norm CUTWEIGHT 1

    QUL                  2650
    QLL                  810
    QRATE                500
    MODE1DWELL           2.0
    MODE3ADWELL          0.24
    MODE3EDWELL          0.24
    MODE4ADWELL          0.24
    MODE4EDWELL          0.24
    MODE5DWELL           1.0
    MODE3CPCDELTA        100.0
    MODE3DPCDELTA        101.0
    MODE4CPCDELTA        100.0
    MODE4DPCDELTA        101.0

    CHN
           SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
           LOXGAIN       0.0
           FUELGAIN      -0.4
           LOXOFFST      0
           FUELOFFST     0
           TIMEGAIN      0
           TIMESTART     0
           TIMESTOP      0
           MODE0UL       2650
           MODE0LL       810
           MODE1UL       50
           MODE1LL       50
           MODE1SD       50
           MODE1FACT     3.0
           MODE2UL       60
           MODE2LL       60
           MODE2FACT     3.0
           MODE3GAIN     50
           MODE3S1UL     200
           MODE3S1LL     200
           MODE3S2UL     200
           MODE3S2LL     200
           MODE3S3UL     200
           MODE3S3LL     200
           MODE4GAIN     -46
           MODE4S1UL     200
           MODE4S1LL     200
           MODE4S2UL     200
           MODE4S2LL     200
           MODE4S3UL     200
           MODE4S3LL     200
```

PARAM HPFTP_TURBINE_DIS_TEMP_CH_B norm CUTWEIGHT 1

QUL	2650
QLL	810
QRATE	500
MODE1DWELL	2.0
MODE3ADWELL	0.24
MODE3EDWELL	0.24
MODE4ADWELL	0.24
MODE4EDWELL	0.24
MODE5DWELL	1.0
MODE3CPCDELTA	11.0
MODE3DPCDELTA	26.0
MODE4CPCDELTA	11.0
MODE4DPCDELTA	26.0

CHN

SAMPLEWTS	0.05	0.05	0.1	0.2	C.6
LOXGAIN	0.0				
FUELGAIN	-0.4				
LOXOFFST	0				
FUELOFFST	0				
TIMEGAIN	0				
TIMESTART	0				
TIMESTOP	0				
MODE0UL	2650				
MODE0LL	810				
MODE1UL	50				
MODE1LL	50				
MODE1SD	50				
MODE1FACT	3.0				
MODE2UL	60				
MODE2LL	60				
MODE2FACT	3.0				
MODE3GAIN	51				
MODE3S1UL	200				
MODE3S1LL	200				
MODE3S2UL	200				
MODE3S2LL	200				
MODE3S3UL	200				
MODE3S3LL	200				
MODE4GAIN	-44				
MODE4S1UL	200				
MODE4S1LL	200				
MODE4S2UL	200				
MODE4S2LL	200				
MODE4S3UL	200				
MODE4S3LL	200				

```
PARAM HPOTP_BOOST_PUMP_RADIAL_ACCEL  type2  CUTWEIGHT 1

        QUL                 30
        QLL                 0
        QRATE               18
        MODE1DWELL          2.0
        MODE3ADWELL         0.24
        MODE3EDWELL         0.24
        MODE4ADWELL         0.24
        MODE4EDWELL         0.24
        MODE5DWELL          0.2
        MODE3CPCDELTA       100.0
        MODE3DPCDELTA       101.0
        MODE4CPCDELTA       100.0
        MODE4DPCDELTA       101.0

        CHN
              SAMPLEWTS     0.05  0.05  0.1   0.2   0.6
              LOXGAIN       0
              FUELGAIN      0
              LOXOFFST      0
              FUELOFFST     0
              PCREFLMTS     65    5.5   0
                            90    7.0   0
                            100   8.0   0
                            104   9.0   0
                            109   9.5   0
                            111   9.5   0
```

```
PARAM HPOTP_DISCHARGE_PRESSURE   norm  CUTWEIGHT  1

      QUL                 7000
      QLL                 0
      QRATE               3000
      MODE1DWELL          2.0
      MODE3ADWELL         0.24
      MODE3EDWELL         0.48
      MODE4ADWELL         0.34
      MODE4EDWELL         0.24
      MODE5DWELL          1.0
      MODE3CPCDELTA       16.0
      MODE3DPCDELTA       101.0
      MODE4CPCDELTA       16.0
      MODE4DPCDELTA       101.0

      CHN
            SAMPLEWTS     0.05  0.05  0.1   0.2   0.6
            LOXGAIN       0
            FUELGAIN      0
            LOXOFFST      0
            FUELOFFST     0
            TIMEGAIN      0
            TIMESTART     0
            TIMESTOP      0
            MODE0UL       7000
            MODE0LL       0
            MODE1UL       140
            MODE1LL       140
            MODE1SD       140
            MODE1FACT     3.0
            MODE2UL       55
            MODE2LL       55
            MODE2FACT     3.0
            MODE3GAIN     434
            MODE3S1UL     450
            MODE3S1LL     450
            MODE3S2UL     450
            MODE3S2LL     450
            MODE3S3UL     450
            MODE3S3LL     450
            MODE4GAIN     -457
            MODE4S1UL     450
            MODE4S1LL     450
            MODE4S2UL     450
            MODE4S2LL     450
            MODE4S3UL     450
            MODE4S3LL     450
```

```
PARAM HPOTP_IMSL_PURGE_PRESS  norm CUTWEIGHT 1

        QUL                 650
        QLL                 0
        QRATE               200
        MODE1DWELL          2.0
        MODE3ADWELL         0.24
        MODE3EDWELL         0.24
        MODE4ADWELL         0.24
        MODE4EDWELL         0.24
        MODE5DWELL          0.2
        MODE3CPCDELTA       100.0
        MODE3DPCDELTA       101.0
        MODE4CPCDELTA       100.0
        MODE4DPCDELTA       101.0

        CHN
                SAMPLEWTS   0.05   0.05   0.1   0.2   0.6
                LOXGAIN     0
                FUELGAIN    0
                LOXOFFST    0
                FUELOFFST   0
                TIMEGAIN    .2
                TIMESTART   7
                TIMESTOP    250
                MODE0UL     650.0
                MODE0LL     0
                MODE1UL     5.0
                MODE1LL     5.0
                MODE1SD     5.0
                MODE1FACT   3.0
                MODE2UL     40.0
                MODE2LL     30.0
                MODE2FACT   3.0
                MODE3GAIN   3.14
                MODE3S1UL   22.0
                MODE3S1LL   22.0
                MODE3S2UL   22.0
                MODE3S2LL   22.0
                MODE3S3UL   22.0
                MODE3S3LL   22.0
                MODE4GAIN   -4.92
                MODE4S1UL   22.0
                MODE4S1LL   22.0
                MODE4S2UL   22.0
                MODE4S2LL   22.0
                MODE4S3UL   22.0
                MODE4S3LL   22.0
```

```
PARAM HPOTP_BOOST_PUMP_DIS_PRESSURE  norm  CUTWEIGHT 1

    QUL              9500
    QLL              0
    QRATE            4700
    MODE1DWELL       2.0
    MODE3ADWELL      0.24
    MODE3EDWELL      0.48
    MODE4ADWELL      0.24
    MODE4EDWELL      0.24
    MODE5DWELL       1.0
    MODE3CPCDELTA    16.0
    MODE3DPCDELTA    101.0
    MODE4CPCDELTA    16.0
    MODE4DPCDELTA    101.0

    CHN
          SAMPLEWTS   0.05   0.05   0.1   0.2   0.6
          LOXGAIN     -1.0
          FUELGAIN    0.2
          LOXOFFST    0
          FUELOFFST   0
          TIMEGAIN    0
          TIMESTART   0
          TIMESTOP    0
          MODE0UL     9500
          MODE0LL     0
          MODE1UL     90
          MODE1LL     90
          MODE1SD     90
          MODE1FACT   3.0
          MODE2UL     150
          MODE2LL     150
          MODE2FACT   3.0
          MODE3GAIN   791
          MODE3S1UL   1000
          MODE3S1LL   1000
          MODE3S2UL   1000
          MODE3S2LL   1000
          MODE3S3UL   1000
          MODE3S3LL   1000
          MODE4GAIN   -851
          MODE4S1UL   1000
          MODE4S1LL   1000
          MODE4S2UL   1000
          MODE4S2LL   1000
          MODE4S3UL   1000
          MODE4S3LL   1000
```

```
PARAM HPOTP_SEC_SEAL_CAVITY_PR  type1  CUTWEIGHT 1

        QUL               300
        QLL               4
        QRATE             180
        MODE1DWELL        2.0
        MODE3ADWELL       0.24
        MODE3EDWELL       0.24
        MODE4ADWELL       0.24
        MODE4EDWELL       0.24
        MODE5DWELL        0.2
        MODE3CPCDELTA     16.0
        MODE3DPCDELTA     101.0
        MODE4CPCDELTA     16.0
        MODE4DPCDELTA     101.0

        CHN
              SAMPLEWTS   0.05   0.05   0.1   0.2   0.6
              LOXGAIN     0
              FUELGAIN    0
              LOXOFFST    0
              FUELOFFST   0.
              TIMEGAIN    -.1
              TIMESTART   0
              TIMESTOP    57
              MODE0UL     300
              MODE0LL     4
              MODE1UL     3.0
              MODE1LL     3.0
              MODE1SD     3.0
              MODE1FACT   3.0
              MODE2UL     10
              MODE2LL     10
              MODE2FACT   3.0
              MODE3GAIN   .478
              MODE3S1UL   20.0
              MODE3S1LL   20.0
              MODE3S2UL   20.0
              MODE3S2LL   20.0
              MODE3S3UL   20.0
              MODE3S3LL   20.0
              MODE4GAIN   -.736
              MODE4S1UL   20.0
              MODE4S1LL   20.0
              MODE4S2UL   20.0
              MODE4S2LL   20.0
              MODE4S3UL   20.0
              MODE4S3LL   20.0
```

PARAM HPOTP_TURBINE_DIS_TEMP_CH_A norm CUTWEIGHT 1

QUL	2650
QLL	810
QRATE	500
MODE1DWELL	2.0
MODE3ADWELL	0.84
MODE3EDWELL	0.84
MODE4ADWELL	0.84
MODE4EDWELL	0.84
MODE5DWELL	3.0
MODE3CPCDELTA	100.0
MODE3DPCDELTA	101.0
MODE4CPCDELTA	100.0
MODE4DPCDELTA	101.0

CHN

SAMPLEWTS	0.05	0.05	0.1	0.2	0.6
LOXGAIN	-0.45				
FUELGAIN	.3				
LOXOFFST	0				
FUELOFFST	0				
TIMEGAIN	0				
TIMESTART	0				
TIMESTOP	0				
MODE0UL	2650				
MODE0LL	150				
MODE1UL	75				
MODE1LL	75				
MODE1SD	75				
MODE1FACT	3.0				
MODE2UL	100				
MODE2LL	100				
MODE2FACT	3.0				
MODE3GAIN	56				
MODE3S1UL	350				
MODE3S1LL	350				
MODE3S2UL	350				
MODE3S2LL	350				
MODE3S3UL	350				
MODE3S3LL	350				
MODE4GAIN	-65				
MODE4S1UL	350				
MODE4S1LL	350				
MODE4S2UL	350				
MODE4S2LL	350				
MODE4S3UL	350				
MODE4S3LL	350				

```
PARAM HPOTP_TURBINE_DIS_TEMP_CH_B  norm  CUTWEIGHT 1

    QUL               2650
    QLL               810
    QRATE             500
    MODE1DWELL        2.0
    MODE3ADWELL       0.84
    MODE3EDWELL       0.84
    MODE4ADWELL       0.84
    MODE4EDWELL       0.84
    MODE5DWELL        3.0
    MODE3CPCDELTA     100.0
    MODE3DPCDELTA     101.0
    MODE4CPCDELTA     100.0
    MODE4DPCDELTA     101.0

    CHN
          SAMPLEWTS   0.05  0.05  0.1   0.2   0.6
          LOXGAIN     -0.45
          FUELGAIN    .3
          LOXOFFST    0
          FUELOFFST   0
          TIMEGAIN    0
          TIMESTART   0
          TIMESTOP    0
          MODE0UL     2650
          MODE0LL     150
          MODE1UL     75
          MODE1LL     75
          MODE1SD     75
          MODE1FACT   3.0
          MODE2UL     100
          MODE2LL     100
          MODE2FACT   3.0
          MODE3GAIN   58
          MODE3S1UL   350
          MODE3S1LL   350
          MODE3S2UL   350
          MODE3S2LL   350
          MODE3S3UL   350
          MODE3S3LL   350
          MODE4GAIN   -66
          MODE4S1UL   350
          MODE4S1LL   350
          MODE4S2UL   350
          MODE4S2LL   350
          MODE4S3UL   350
          MODE4S3LL   350
```

```
PARAM LPFTP_SHAFT_SPEED  norm CUTWEIGHT 1

    QUL                 20000
    QLL                 0
    QRATE               12000
    MODE1DWELL          2.0
    MODE3ADWELL         0.36
    MODE3EDWELL         0.48
    MODE4ADWELL         0.36
    MODE4EDWELL         0.24
    MODE5DWELL          1.0
    MODE3CPCDELTA       16.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       16.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05   0.05   0.1   0.2   0.6
          LOXGAIN       -0.7
          FUELGAIN      -1.2
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       20000
          MODE0LL       0
          MODE1UL       225
          MODE1LL       225
          MODE1SD       225
          MODE1FACT     3.0
          MODE2UL       225
          MODE2LL       225
          MODE2FACT     3.0
          MODE3GAIN     647
          MODE3S1UL     1100
          MODE3S1LL     1100
          MODE3S2UL     1100
          MODE3S2LL     1100
          MODE3S3UL     1100
          MODE3S3LL     1100
          MODE4GAIN     -637
          MODE4S1UL     1100
          MODE4S1LL     1100
          MODE4S2UL     1100
          MODE4S2LL     1100
          MODE4S3UL     1100
          MODE4S3LL     1100
```

PARAM LPOTP_PUMP_DISCHARGE_PRESSURE norm CUTWEIGHT 1

```
QUL             600
QLL             0
QRATE           200
MODE1DWELL      2.0
MODE3ADWELL     0.24
MODE3EDWELL     0.24
MODE4ADWELL     0.44
MODE4EDWELL     0.24
MODE5DWELL      0.4
MODE3CPCDELTA   100.0
MODE3DPCDELTA   101.0
MODE4CPCDELTA   100.0
MODE4DPCDELTA   101.0

CHN
      SAMPLEWTS   0.05  0.05  0.1  0.2  0.6
      LOXGAIN     0.85
      FUELGAIN    0
      LOXOFFST    0
      FUELOFFST   0
      TIMEGAIN    0
      TIMESTART   0
      TIMESTOP    0
      MODE0UL     600
      MODE0LL     0
      MODE1UL     10.0
      MODE1LL     10.0
      MODE1SD     10.0
      MODE1FACT   3.0
      MODE2UL     10.0
      MODE2LL     10.0
      MODE2FACT   3.0
      MODE3GAIN   14.9
      MODE3S1UL   40.0
      MODE3S1LL   40.0
      MODE3S2UL   40.0
      MODE3S2LL   40.0
      MODE3S3UL   40.0
      MODE3S3LL   40.0
      MODE4GAIN   -14.3
      MODE4S1UL   40.0
      MODE4S1LL   40.0
      MODE4S2UL   40.0
      MODE4S2LL   40.0
      MODE4S3UL   40.0
      MODE4S3LL   40.0
```

PARAM MCC_PRESSURE norm CUTWEIGHT 1

QUL	3500				
QLL	0				
QRATE	2100				
MODE1DWELL	2.0				
MODE3ADWELL	0.24				
MODE3EDWELL	0.48				
MODE4ADWELL	0.14				
MODE4EDWELL	0.24				
MODE5DWELL	0.6				
MODE3CPCDELTA	9.0				
MODE3DPCDELTA	26.0				
MODE4CPCDELTA	9.0				
MODE4DPCDELTA	26.0				
CHN					
SAMPLEWTS	0.05	0.05	0.1	0.2	0.6
LOXGAIN	0				
FUELGAIN	0				
LOXOFFST	0				
FUELOFFST	0				
TIMEGAIN	0				
TIMESTART	0				
TIMESTOP	0				
MODE0UL	3500				
MODE0LL	0				
MODE1UL	60				
MODE1LL	60				
MODE1SD	60				
MODE1FACT	3.0				
MODE2UL	30				
MODE2LL	30				
MODE2FACT	3.0				
MODE3GAIN	293				
MODE3S1UL	350				
MODE3S1LL	350				
MODE3S2UL	350				
MODE3S2LL	350				
MODE3S3UL	350				
MODE3S3LL	350				
MODE4GAIN	-308				
MODE4S1UL	350				
MODE4S1LL	350				
MODE4S2UL	350				
MODE4S2LL	350				
MODE4S3UL	350				
MODE4S3LL	350				

```
PARAM MCC_LINER_CAVITY_PRESSURE type1  CUTWEIGHT 1

        QUL                 100
        QLL                 -100
        QRATE               120
        MODE1DWELL          2.0
        MODE3ADWELL         0.24
        MODE3EDWELL         0.24
        MODE4ADWELL         0.24
        MODE4EDWELL         0.24
        MODE5DWELL          0.2
        MODE3CPCDELTA       100.0
        MODE3DPCDELTA       101.0
        MODE4CPCDELTA       100.0
        MODE4DPCDELTA       101.0

        CHN
              SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
              LOXGAIN       0
              FUELGAIN      0
              LOXOFFST      0
              FUELOFFST     0
              TIMEGAIN      0
              TIMESTART     0
              TIMESTOP      0
              MODE0UL       100.0
              MODE0LL       -100.0
              MODE1UL       3.3
              MODE1LL       0.6
              MODE1SD       3.3
              MODE1FACT     3.0
              MODE2UL       3.3
              MODE2LL       0.6
              MODE2FACT     3.0
              MODE3GAIN     0
              MODE3S1UL     3.3
              MODE3S1LL     3.3
              MODE3S2UL     3.3
              MODE3S2LL     3.3
              MODE3S3UL     3.3
              MODE3S3LL     3.3
              MODE4GAIN     0
              MODE4S1UL     3.3
              MODE4S1LL     3.3
              MODE4S2UL     3.3
              MODE4S2LL     3.3
              MODE4S3UL     3.3
              MODE4S3LL     3.3
```

PARAM OPOV_ACT_POSITION norm CUTWEIGHT 1

QUL	105
QLL	0
QRATE	20
MODE1DWELL	2.0
MODE3ADWELL	0
MODE3EDWELL	.24
MODE4ADWELL	0
MODE4EDWELL	0
MODE5DWELL	1.0
MODE3CPCDELTA	11.0
MODE3DPCDELTA	101.0
MODE4CPCDELTA	11.0
MODE4DPCDELTA	101.0

CHN

SAMPLEWTS	0.05	0.05	0.1	0.2	0.6
LOXGAIN	-0.02				
FUELGAIN	0				
LOXOFFST	0				
FUELOFFST	0				
TIMEGAIN	0				
TIMESTART	0				
TIMESTOP	0				
MODE0UL	105				
MODE0LL	0				
MODE1UL	3.0				
MODE1LL	3.0				
MODE1SD	3.0				
MODE1FACT	3.0				
MODE2UL	6.0				
MODE2LL	6.0				
MODE2FACT	3.0				
MODE3GAIN	3.46				
MODE3S1UL	12.0				
MODE3S1LL	12.0				
MODE3S2UL	12.0				
MODE3S2LL	12.0				
MODE3S3UL	12.0				
MODE3S3LL	12.0				
MODE4GAIN	-3.47				
MODE4S1UL	12.0				
MODE4S1LL	12.0				
MODE4S2UL	12.0				
MODE4S2LL	12.0				
MODE4S3UL	12.0				
MODE4S3LL	12.0				

Table II
Adaptation Data for Pratt LOX Pump w/ Nominal CCV Schedule

```
/* adaptation data using 10 samples from 904 NC for gains
   for PW LOX pump w/ nominal CCV schedule */

COLIMIT 3      /* data for safd_4 algorithm */
RPL 3006.0     /* pcref at 100% */
GOXVALVE
   CLOSE        500.0  /* <time>*/

FUELVALVE
   CLOSE        500.0 /* <time>*/

LPOP_INLET_PR
   QUL          200.0
   QLL          0.0
   QRATE        120.0

LPFP_INLET_PR
   QUL          100.0
   QLL          0.0
   QRATE        60.0
```

```
PARAM     FPOV_POS  norm  CUTWEIGHT 1

   QUL                 105.0
   QLL                 0.0
   QRATE               20.0
   MODE1DWELL          2.0
   MODE3ADWELL         0
   MODE3EDWELL         .24
   MODE4ADWELL         0
   MODE4EDWELL         0
   MODE5DWELL          1.0
   MODE3CPCDELTA       100.0
   MODE3DPCDELTA       101.0
   MODE4CPCDELTA       100.0
   MODE4DPCDELTA       101.0

   CHN
          SAMPLEWTS    0.05   0.05   0.1   0.2   0.6
          LOXGAIN      0.01
          FUELGAIN     -.02
          LOXOFFST     0
          FUELOFFST    0
          TIMEGAIN     0
          TIMESTART    0
          TIMESTOP     0
          MODE0UL      105.0
          MODE0LI      0.0
          MODE1UL      1.4
          MODE1LL      1.4
          MODE1SD      1.4
          MODE1FACT    3.0
          MODE2UL      2.0
          MODE2LL      2.0
          MODE2FACT    3.0
          MODE3GAIN    4.35
          MODE3S1UL    6.5
          MODE3S1LL    6.5
          MODE3S2UL    6.5
          MODE3S2LL    6.5
          MODE3S3UL    6.5
          MODE3S3LL    6.5
          MODE4GAIN    -4.23
          MODE4S1UL    6.5
          MODE4S1LL    6.5
          MODE4S2UL    6.5
          MODE4S2LL    6.5
          MODE4S3UL    6.5
          MODE4S3LL    6.5
```

```
PARAM     FUEL_FLOW  norm  CUTWEIGHT 1

   QUL                  24000
   QLL                  0
   QRATE                14400
   MODE1DWELL           2.0
   MODE3ADWELL          0.28
   MODE3EDWELL          0.12
   MODE4ADWELL          0.28
   MODE4EDWELL          0.12
   MODE5DWELL           0.2
   MODE3CPCDELTA        11.0
   MODE3DPCDELTA        101.0
   MODE4CPCDELTA        11.0
   MODE4DPCDELTA        101.0

   CHN
         SAMPLEWTS      0.05   0.05   0.1    0.2    0.6
         LOXGAIN        0
         FUELGAIN       -2.1
         LOXOFFST       0
         FUELOFFST      0
         TIMEGAIN       0
         TIMESTART      0
         TIMESTOP       0
         MODE0UL        24000
         MODE0LL        0
         MODE1UL        250
         MODE1LL        250
         MODE1SD        250
         MODE1FACT      3.0
         MODE2UL        350
         MODE2LL        350
         MODE2FACT      3.0
         MODE3GAIN      1513
         MODE3S1UL      1000
         MODE3S1LL      1000
         MODE3S2UL      1000
         MODE3S2LL      1000
         MODE3S3UL      1000
         MODE3S3LL      1000
         MODE4GAIN      -1608
         MODE4S1UL      1000
         MODE4S1LL      1000
         MODE4S2UL      1000
         MODE4S2LL      1000
         MODE4S3UL      1000
         MODE4S3LL      1000
```

```
/*PARAM  HEX_BYPASS_MIX_INTERFACE_TEMP  norm  CUTWEIGHT 1

    QUL              500
    QLL              -300
    QRATE            480
    MODE1DWELL       2.0
    MODE3ADWELL      0.24
    MODE3EDWELL      0.24
    MODE4ADWELL      0.24
    MODE4EDWELL      0.24
    MODE5DWELL       0.2
    MODE3CPCDELTA    100.0
    MODE3DPCDELTA    101.0
    MODE4CPCDELTA    100.0
    MODE4DPCDELTA    101.0

    CHN
          SAMPLEWTS  0.05   0.05   0.1    0.2    0.6
          LOXGAIN    -1.0
          FUELGAIN   0
          LOXOFFST   0
          FUELOFFST  0
          TIMEGAIN   0
          TIMESTART  0
          TIMESTOP   0
          MODE0UL    500
          MODE0LL    -300
          MODE1UL    40.0
          MODE1LL    50.0
          MODE1SD    0
          MODE1FACT  3.0
          MODE2UL    40.0
          MODE2LL    50.0
          MODE2FACT  3.0
          MODE3GAIN  0
          MODE3S1UL  0
          MODE3S1LL  0
          MODE3S2UL  0
          MODE3S2LL  0
          MODE3S3UL  0
          MODE3S3LL  0
          MODE4GAIN  0
          MODE4S1UL  0
          MODE4S1LL  0
          MODE4S2UL  0
          MODE4S2LL  0
          MODE4S3UL  0
          MODE4S3LL  0
```

```
*/
/*PARAM  HEX_VENTURI_DELTA_PRESSURE  norm CUTWEIGHT 1

    QUL                 500
    QLL                 -500
    QRATE               600
    MODE1DWELL          2.0
    MODE3ADWELL         0.24
    MODE3EDWELL         0.24
    MODE4ADWELL         0.24
    MODE4EDWELL         0.24
    MODE5DWELL          0.2
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
          LOXGAIN       -0.07
          FUELGAIN      0
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       500.0
          MODE0LL       -500.0
          MODE1UL       5.0
          MODE1LL       5.0
          MODE1SD       0
          MODE1FACT     3.0
          MODE2UL       5.0
          MODE2LL       5.0
          MODE2FACT     3.0
          MODE3GAIN     0
          MODE3S1UL     0
          MODE3S1LL     0
          MODE3S2UL     0
          MODE3S2LL     0
          MODE3S3UL     0
          MODE3S3LL     0
          MODE4GAIN     0
          MODE4S1UL     0
          MODE4S1LL     0
          MODE4S2UL     0
          MODE4S2LL     0
          MODE4S3UL     0
          MODE4S3LL     0
```

```
*/
PARAM     HPFTP_ACCEL  type2  CUTWEIGHT 1

    QUL                 30
    QLL                 0
    QRATE               18
    MODE1DWELL          2.0
    MODE3ADWELL         0.24
    MODE3EDWELL         0.24
    MODE4ADWELL         0.24
    MODE4EDWELL         0.24
    MODE5DWELL          0.2
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       100.0

    CHN
            SAMPLEWTS   0.05   0.05   0.1   0.2   0.6
            LOXGAIN            0
            FUELGAIN    0
            LOXOFFST    0
            FUELOFFST   0
            PCREFLMTS   65     8.0    0
                        90     8.5    0
                        100    9.0    0
                        104    9.5    0
                        109    10.0   0
                        111    10.0   0
```

```
PARAM    HPFTP_BALANCE_CAVITY_PRESSURE  norm CUTWEIGHT 1

    QUL                 10000
    QLL                 0
    QRATE               4000
    MODE1DWELL          2.0
    MODE3ADWELL         0.28
    MODE3EDWELL         0.48
    MODE4ADWELL         0.28
    MODE4EDWELL         0.24
    MODE5DWELL          1.0
    MODE3CPCDELTA       10.0
    MODE3DPCDELTA       11.0
    MODE4CPCDELTA       10.0
    MODE4DPCDELTA       11.0

    CHN
          SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
          LOXGAIN       0
          FUELGAIN      0
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       10000.0
          MODE0LL       0
          MODE1UL       100
          MODE1LL       100
          MODE1SD       50
          MODE1FACT     3.0
          MODE2UL       100
          MODE2LL       100
          MODE2FACT     3.0
          MODE3GAIN     423.9
          MODE3S1UL     300
          MODE3S1LL     300
          MODE3S2UL     300
          MODE3S2LL     300
          MODE3S3UL     300
          MODE3S3LL     300
          MODE4GAIN     -464.5
          MODE4S1UL     300
          MODE4S1LL     300
          MODE4S2UL     300
          MODE4S2LL     300
          MODE4S3UL     300
          MODE4S3LL     300
```

```
PARAM    HPFTP_COOLANT_LINER_PRESSURE   norm   CUTWEIGHT 1

    QUL              7000
    QLL              1800
    QRATE            4200
    MODE1DWELL       2.0
    MODE3ADWELL      0.24
    MODE3EDWELL      0.48
    MODE4ADWELL      0.24
    MODE4EDWELL      0.24
    MODE5DWELL       1.0
    MODE3CPCDELTA    11.0
    MODE3DPCDELTA    26.0
    MODE4CPCDELTA    11.0
    MODE4DPCDELTA    26.0

    CHN
          SAMPLEWTS  0.05   0.05   0.1   0.2   0.6
          LOXGAIN    0
          FUELGAIN   0
          LOXOFFST   0
          FUELOFFST  0
          TIMEGAIN   0
          TIMESTART  0
          TIMESTOP   0
          MODE0UL    7000
          MODE0LL    1800
          MODE1UL    75
          MODE1LL    75
          MODE1SD    75
          MODE1FACT  3.0
          MODE2UL    60
          MODE2LL    60
          MODE2FACT  3.0
          MODE3GAIN  318
          MODE3S1UL  95
          MODE3S1LL  500
          MODE3S2UL  500
          MODE3S2LL  500
          MODE3S3UL  500
          MODE3S3LL  500
          MODE4GAIN  -351
          MODE4S1UL  500
          MODE4S1LL  500
          MODE4S2UL  500
          MODE4S2LL  500
          MODE4S3UL  500
          MODE4S3LL  500
```

```
PARAM    HPFTP_DISCHARGE_PRESSURE  norm  CUTWEIGHT 1

   QUL                 9500
   QLL                 0
   QRATE               5700
   MODE1DWELL          2.0
   MODE3ADWELL         0.28
   MODE3EDWELL         0.36
   MODE4ADWELL         0.36
   MODE4EDWELL         0.24
   MODE5DWELL          1.0
   MODE3CPCDELTA       100.0
   MODE3DPCDELTA       101.0
   MODE4CPCDELTA       100.0
   MODE4DPCDELTA       101.0

   CHN
         SAMPLEWTS     0.05  0.05  0.1   0.2   0.6
         LOXGAIN       -0.25
         FUELGAIN      -0.2
         LOXOFFST      0
         FUELOFFST     0
         TIMEGAIN      0
         TIMESTART     0
         TIMESTOP      0
         MODE0UL       9500
         MODE0LL       0
         MODE1UL       150
         MODE1LL       150
         MODE1SD       150
         MODE1FACT     3.0
         MODE2UL       80
         MODE2LL       80
         MODE2FACT     3.0
         MODE3GAIN     550
         MODE3S1UL     850
         MODE3S1LL     850
         MODE3S2UL     850
         MODE3S2LL     850
         MODE3S3UL     850
         MODE3S3LL     850
         MODE4GAIN     -605
         MODE4S1UL     850
         MODE4S1LL     850
         MODE4S2UL     850
         MODE4S2LL     850
         MODE4S3UL     850
         MODE4S3LL     850
```

```
PARAM     HPFTP_SHAFT_SPEED norm  OUTWEIGHT 1

    QUL                 45000
    QLL                 0
    QRATE               27000
    MODE1DWELL          2.0
    MODE3ADWELL         0.24
    MODE3EDWELL         0.24
    MODE4ADWELL         0.24
    MODE4EDWELL         0.24
    MODE5DWELL          1.0
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
          LOXGAIN       0
          FUELGAIN      -4.9
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       45000
          MODE0LL       0
          MODE1UL       400
          MODE1LL       400
          MODE1SD       400
          MODE1FACT     3.0
          MODE2UL       300
          MODE2LL       300
          MODE2FACT     3.0
          MODE3GAIN     2047
          MODE3S1UL     2500
          MODE3S1LL     2500
          MODE3S2UL     2500
          MODE3S2LL     2500
          MODE3S3UL     2500
          MODE3S3LL     2500
          MODE4GAIN     -2199
          MODE4S1UL     2500
          MODE4S1LL     2500
          MODE4S2UL     2500
          MODE4S2LL     2500
          MODE4S3UL     2500
          MODE4S3LL     2500
```

```
PARAM     HPFTP_TURBINE_DIS_TEMP_CH_A  norm CUTWEIGHT 1

    QUL              2650
    QLL              810
    QRATE            500
    MODE1DWELL       2.0
    MODE3ADWELL      0.24
    MODE3EDWELL      0.24
    MODE4ADWELL      0.24
    MODE4EDWELL      0.24
    MODE5DWELL       1.0
    MODE3CPCDELTA    100.0
    MODE3DPCDELTA    101.0
    MODE4CPCDELTA    100.0
    MODE4DPCDELTA    101.0

    CHN
        SAMPLEWTS    0.05   0.05   0.1   0.2   0.6
        LOXGAIN      0.0
        FUELGAIN     -0.4
        LOXOFFST     0
        FUELOFFST    0
        TIMEGAIN     0
        TIMESTART    0
        TIMESTOP     0
        MODE0UL      2650
        MODE0LL      810
        MODE1UL      50
        MODE1LL      50
        MODE1SD      50
        MODE1FACT    3.0
        MODE2UL      60
        MODE2LL      60
        MODE2FACT    3.0
        MODE3GAIN    58
        MODE3S1UL    200
        MODE3S1LL    200
        MODE3S2UL    200
        MODE3S2LL    200
        MODE3S3UL    200
        MODE3S3LL    200
        MODE4GAIN    -61
        MODE4S1UL    200
        MODE4S1LL    200
        MODE4S2UL    200
        MODE4S2LL    200
        MODE4S3UL    200
        MODE4S3LL    200
```

```
PARAM    HPFTP_TURBINE_DIS_TEMP_CH_B norm CUTWEIGHT 1

    QUL                 2650
    QLL                 810
    QRATE               500
    MODE1DWELL          2.0
    MODE3ADWELL         0.24
    MODE3EDWELL         0.24
    MODE4ADWELL         0.24
    MODE4EDWELL         0.24
    MODE5DWELL          1.0
    MODE3CPCDELTA       11.0
    MODE3DPCDELTA       26.0
    MODE4CPCDELTA       11.0
    MODE4DPCDELTA       26.0

    CHN
          SAMPLEWTS     0.05  0.05  0.1   0.2   0.6
          LOXGAIN       0.0
          FUELGAIN      -0.4
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       2650
          MODE0LL       810
          MODE1UL       50
          MODE1LL       50
          MODE1SD       50
          MODE1FACT     3.0
          MODE2UL       60
          MODE2LL       60
          MODE2FACT     3.0
          MODE3GAIN     69
          MODE3S1UL     200
          MODE3S1LL     200
          MODE3S2UL     200
          MODE3S2LL     200
          MODE3S3UL     200
          MODE3S3LL     200
          MODE4GAIN     -71
          MODE4S1UL     200
          MODE4S1LL     200
          MODE4S2UL     200
          MODE4S2LL     200
          MODE4S3UL     200
          MODE4S3LL     200
```

```
PARAM    HPOTP_BOOST_PUMP_RADIAL_ACCEL  type2  CUTWEIGHT 1

   QUL                  30
   QLL                  0
   QRATE                18
   MODE1DWELL           2.0
   MODE3ADWELL          0.24
   MODE3EDWELL          0.24
   MODE4ADWELL          0.24
   MODE4EDWELL          0.24
   MODE5DWELL           0.2
   MODE3CPCDELTA        100.0
   MODE3DPCDELTA        101.0
   MODE4CPCDELTA        100.0
   MODE4DPCDELTA        101.0

   CHN
         SAMPLEWTS      0.05  0.05  0.1   0.2   0.6
         LOXGAIN        0
         FUELGAIN       0
         LOXOFFST       0
         FUELOFFST      0
         PCREFLMTS      65    5.5   0
                        90    7.0   0
                        100   8.0   0
                        104   9.0   0
                        109   9.5   0
                        111   9.5   0
```

```
PARAM     HPOTP_DISCHARGE_PRESSURE    norm  CUTWEIGHT  1

   QUL                 7000
   QLL                 0
   QRATE               3000
   MODE1DWELL          2.0
   MODE3ADWELL         0.24
   MODE3EDWELL         0.48
   MODE4ADWELL         0.34
   MODE4EDWELL         0.24
   MODE5DWELL          1.0
   MODE3CPCDELTA       16.0
   MODE3DPCDELTA       101.0
   MODE4CPCDELTA       16.0
   MODE4DPCDELTA       101.0

   CHN
         SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
         LOXGAIN       0
         FUELGAIN      0
         LOXOFFST      0
         FUELOFFST     0
         TIMEGAIN      0
         TIMESTART     0
         TIMESTOP      0
         MODE0UL       7000
         MODE0LL       0
         MODE1UL       140
         MODE1LL       140
         MODE1SD       140
         MODE1FACT     3.0
         MODE2UL       55
         MODE2LL       55
         MODE2FACT     3.0
         MODE3GAIN     407
         MODE3S1UL     450
         MODE3S1LL     450
         MODE3S2UL     450
         MODE3S2LL     450
         MODE3S3UL     450
         MODE3S3LL     450
         MODE4GAIN     -462
         MODE4S1UL     450
         MODE4S1LL     450
         MODE4S2UL     450
         MODE4S2LL     450
         MODE4S3UL     450
         MODE4S3LL     450
```

```
PARAM     HPOTP_IMSL_PURGE_PRESS   norm CUTWEIGHT 1

   QUL                  650
   QLL                  0
   QRATE                200
   MODE1DWELL           2.0
   MODE3ADWELL          0.24
   MODE3EDWELL          0.24
   MODE4ADWELL          0.24
   MODE4EDWELL          0.24
   MODE5DWELL           0.2
   MODE3CPCDELTA        100.0
   MODE3DPCDELTA        101.0
   MODE4CPCDELTA        100.0
   MODE4DPCDELTA        101.0

   CHN
         SAMPLEWTS      0.05   0.05   0.1    0.2    0.6
         LOXGAIN        0
         FUELGAIN       0
         LOXOFFST       0
         FUELOFFST      0
         TIMEGAIN       0
         TIMESTART      0
         TIMESTOP       0
         MODE0UL        650.0
         MODE0LL        0
         MODE1UL        5.0
         MODE1LL        5.0
         MODE1SD        5.0
         MODE1FACT      3.0
         MODE2UL        10.0
         MODE2LL        10.0
         MODE2FACT      10.0
         MODE3GAIN      .2207
         MODE3S1UL      22.0
         MODE3S1LL      22.0
         MODE3S2UL      22.0
         MODE3S2LL      22.0
         MODE3S3UL      22.0
         MODE3S3LL      22.0
         MODE4GAIN      -.3351
         MODE4S1UL      22.0
         MODE4S1LL      22.0
         MODE4S2UL      22.0
         MODE4S2LL      22.0
         MODE4S3UL      22.0
         MODE4S3LL      22.0
```

```
PARAM     HPOTP_BOOST_PUMP_DIS_PRESSURE   norm   CUTWEIGHT 1

   QUL                  9500
   QLL                  0
   QRATE                4700
   MODE1DWELL           2.0
   MODE3ADWELL          0.24
   MODE3EDWELL          0.48
   MODE4ADWELL          0.24
   MODE4EDWELL          0.24
   MODE5DWELL           1.0
   MODE3CPCDELTA        16.0
   MODE3DPCDELTA        101.0
   MODE4CPCDELTA        16.0
   MODE4DPCDELTA        101.0

   CHN
         SAMPLEWTS      0.05   0.05   0.1    0.2    C.6
         LOXGAIN        -1.0
         FUELGAIN       0.2
         LOXOFFST       0
         FUELOFFST      0
         TIMEGAIN       0
         TIMESTART      0
         TIMESTOP       0
         MODE0UL        9500
         MODE0LL        0
         MODE1UL        90
         MODE1LL        90
         MODE1SD        90
         MODE1FACT      3.0
         MODE2UL        150
         MODE2LL        150
         MODE2FACT      3.0
         MODE3GAIN      700
         MODE3S1UL      1000
         MODE3S1LL      1000
         MODE3S2UL      1000
         MODE3S2LL      1000
         MODE3S3UL      1000
         MODE3S3LL      1000
         MODE4GAIN      -803
         MODE4S1UL      1000
         MODE4S1LL      1000
         MODE4S2UL      1000
         MODE4S2LL      1000
         MODE4S3UL      1000
         MODE4S3LL      1000
```

```
PARAM    HPOTP_SEC_SEAL_CAVITY_PR  type1  CUTWEIGHT 1

    QUL               300
    QLL               4
    QRATE             180
    MODE1DWELL        2.0
    MODE3ADWELL       0.24
    MODE3EDWELL       0.24
    MODE4ADWELL       0.24
    MODE4EDWELL       0.24
    MODE5DWELL        0.2
    MODE3CPCDELTA     16.0
    MODE3DPCDELTA     101.0
    MODE4CPCDELTA     16.0
    MODE4DPCDELTA     101.0

    CHN
          SAMPLEWTS   0.05  0.05  0.1   0.2   0.6
          LOXGAIN     0
          FUELGAIN    0
          LOXOFFST    0
          FUELOFFST   0
          TIMEGAIN    0.05575
          TIMESTART   7.0
          TIMESTOP    500.0
          MODE0UL     300
          MODE0LL     4
          MODE1UL     3.0
          MODE1LL     3.0
          MODE1SD     3.0
          MODE1FACT   3.0
          MODE2UL     10
          MODE2LL     10
          MODE2FACT   3.0
          MODE3GAIN   2.273
          MODE3S1UL   20.0
          MODE3S1LL   20.0
          MODE3S2UL   20.0
          MODE3S2LL   20.0
          MODE3S3UL   20.0
          MODE3S3LL   20.0
          MODE4GAIN   -1.910
          MODE4S1UL   20.0
          MODE4S1LL   20.0
          MODE4S2UL   20.0
          MODE4S2LL   20.0
          MODE4S3UL   20.0
          MODE4S3LL   20.0
```

```
PARAM     HPOTP_TURBINE_DIS_TEMP_CH_A    norm  CUTWEIGHT 1

    QUL                 2650
    QLL                 810
    QRATE               500
    MODE1DWELL          2.0
    MODE3ADWELL         0.84
    MODE3EDWELL         0.84
    MODE4ADWELL         0.84
    MODE4EDWELL         0.84
    MODE5DWELL          3.0
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05  0.05  0.1   0.2   0.6
          LOXGAIN       -0.45
          FUELGAIN      .3
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       2650
          MODE0LL       150
          MODE1UL       75
          MODE1LL       75
          MODE1SD       75
          MODE1FACT     3.0
          MODE2UL       100
          MODE2LL       100
          MODE2FACT     3.0
          MODE3GAIN     31.18
          MODE3S1UL     350
          MODE3S1LL     350
          MODE3S2UL     350
          MODE3S2LL     350
          MODE3S3UL     350
          MODE3S3LL     350
          MODE4GAIN     -45.85
          MODE4S1UL     350
          MODE4S1LL     350
          MODE4S2UL     350
          MODE4S2LL     350
          MODE4S3UL     350
          MODE4S3LL     350
```

```
PARAM     HPOTP_TURBINE_DIS_TEMP_CH_B  norm  CUTWEIGHT 1

    QUL                 2650
    QLL                 810
    QRATE               500
    MODE1DWELL          2.0
    MODE3ADWELL         0.84
    MODE3EDWELL         0.84
    MODE4ADWELL         0.84
    MODE4EDWELL         0.84
    MODE5DWELL          3.0
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05  0.05  0.1   0.2   0.6
          LOXGAIN       -0.45
          FUELGAIN      .3
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       2650
          MODE0LL       150
          MODE1UL       75
          MODE1LL       75
          MODE1SD       75
          MODE1FACT     3.0
          MODE2UL       100
          MODE2LL       100
          MODE2FACT     3.0
          MODE3GAIN     40.02
          MODE3S1UL     350
          MODE3S1LL     350
          MODE3S2UL     350
          MODE3S2LL     350
          MODE3S3UL     350
          MODE3S3LL     350
          MODE4GAIN     -52.41
          MODE4S1UL     350
          MODE4S1LL     350
          MODE4S2UL     350
          MODE4S2LL     350
          MODE4S3UL     350
          MODE4S3LL     350
```

```
PARAM     LPFTP_SHAFT_SPEED   norm CUTWEIGHT 1

   QUL                  20000
   QLL                  0
   QRATE                12000
   MODE1DWELL           2.0
   MODE3ADWELL          0.36
   MODE3EDWELL          0.48
   MODE4ADWELL          0.36
   MODE4EDWELL          0.24
   MODE5DWELL           1.0
   MODE3CPCDELTA        16.0
   MODE3DPCDELTA        101.0
   MODE4CPCDELTA        16.0
   MODE4DPCDELTA        101.0

   CHN
         SAMPLEWTS      0.05   0.05   0.1    0.2    0.6
         LOXGAIN        -0.7
         FUELGAIN       -1.2
         LOXOFFST       0
         FUELOFFST      0
         TIMEGAIN       0
         TIMESTART      0
         TIMESTOP       0
         MODE0UL        20000
         MODE0LL        0
         MODE1UL        225
         MODE1LL        225
         MODE1SD        225
         MODE1FACT      3.0
         MODE2UL        225
         MODE2LL        225
         MODE2FACT      3.0
         MODE3GAIN      586.2
         MODE3S1UL      1100
         MODE3S1LL      1100
         MODE3S2UL      1100
         MODE3S2LL      1100
         MODE3S3UL      1100
         MODE3S3LL      1100
         MODE4GAIN      -644.8
         MODE4S1UL      1100
         MODE4S1LL      1100
         MODE4S2UL      1100
         MODE4S2LL      1100
         MODE4S3UL      1100
         MODE4S3LL      1100
```

```
PARAM     LPOTP_PUMP_DISCHARGE_PRESSURE  norm  CUTWEIGHT 1

    QUL                 600
    QLL                 0
    QRATE               200
    MODE1DWELL          2.0
    MODE3ADWELL         0.24
    MODE3EDWELL         0.24
    MODE4ADWELL         0.44
    MODE4EDWELL         0.24
    MODE5DWELL          0.4
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       101.0

    CHN
            SAMPLEWTS   0.05  0.05  0.1   0.2   0.6
            LOXGAIN     0.85
            FUELGAIN    0
            LOXOFFST    0
            FUELOFFST   0
            TIMEGAIN    0
            TIMESTART   0
            TIMESTOP    0
            MODE0UL     600
            MODE0LL     0
            MODE1UL     10.0
            MODE1LL     10.0
            MODE1SD     10.0
            MODE1FACT   3.0
            MODE2UL     10.0
            MODE2LL     10.0
            MODE2FACT   3.0
            MODE3GAIN   20.01
            MODE3S1UL   40.0
            MODE3S1LL   40.0
            MODE3S2UL   40.0
            MODE3S2LL   40.0
            MODE3S3UL   40.0
            MODE3S3LL   40.0
            MODE4GAIN   -19.66
            MODE4S1UL   40.0
            MODE4S1LL   40.0
            MODE4S2UL   40.0
            MODE4S2LL   40.0
            MODE4S3UL   40.0
            MODE4S3LL   40.0
```

```
PARAM     MCC_PRESSURE  norm  CUTWEIGHT  1

    QUL                  3500
    QLL                  0
    QRATE                2100
    MODE1DWELL           2.0
    MODE3ADWELL          0.24
    MODE3EDWELL          0.48
    MODE4ADWELL          0.14
    MODE4EDWELL          0.24
    MODE5DWELL           0.6
    MODE3CPCDELTA        9.0
    MODE3DPCDELTA        26.0
    MODE4CPCDELTA        9.0
    MODE4DPCDELTA        26.0

    CHN
          SAMPLEWTS      0.05  0.05  0.1   0.2   0.6
          LOXGAIN        0
          FUELGAIN       0
          LOXOFFST       0
          FUELOFFST      0
          TIMEGAIN       0
          TIMESTART      0
          TIMESTOP       0
          MODE0UL        3500
          MODE0LL        0
          MODE1UL        60
          MODE1LL        60
          MODE1SD        60
          MODE1FACT      3.0
          MODE2UL        30
          MODE2LL        30
          MODE2FACT      3.0
          MODE3GAIN      284.8
          MODE3S1UL      350
          MODE3S1LL      350
          MODE3S2UL      350
          MODE3S2LL      350
          MODE3S3UL      350
          MODE3S3LL      350
          MODE4GAIN      -316.0
          MODE4S1UL      350
          MODE4S1LL      350
          MODE4S2UL      350
          MODE4S2LL      350
          MODE4S3UL      350
          MODE4S3LL      350
```

```
PARAM     MCC_LINER_CAVITY_PRESSURE type1  CUTWEIGHT 1

   QUL                100
   QLL                -100
   QRATE              120
   MODE1DWELL         2.0
   MODE3ADWELL        0.24
   MODE3EDWELL        0.24
   MODE4ADWELL        0.24
   MODE4EDWELL        0.24
   MODE5DWELL         0.2
   MODE3CPCDELTA      100.0
   MODE3DPCDELTA      101.0
   MODE4CPCDELTA      100.0
   MODE4DPCDELTA      101.0

   CHN
         SAMPLEWTS    0.05  0.05  0.1   0.2   0.6
         LOXGAIN      0
         FUELGAIN     0
         LOXOFFST     0
         FUELOFFST    0
         TIMEGAIN     0
         TIMESTART    0
         TIMESTOP     0
         MODE0UL      100.0
         MODE0LL      -100.0
         MODE1UL      3.3
         MODE1LL      0.6
         MODE1SD      3.3
         MODE1FACT    3.0
         MODE2UL      3.3
         MODE2LL      0.6
         MODE2FACT    3.0
         MODE3GAIN    0
         MODE3S1UL    3.3
         MODE3S1LL    3.3
         MODE3S2UL    3.3
         MODE3S2LL    3.3
         MODE3S3UL    3.3
         MODE3S3LL    3.3
         MODE4GAIN    0
         MODE4S1UL    3.3
         MODE4S1LL    3.3
         MODE4S2UL    3.3
         MODE4S2LL    3.3
         MODE4S3UL    3.3
         MODE4S3LL    3.3
```

```
PARAM    CPOV_ACT_POSITION  norm  CUTWEIGHT 1

    QUL               105
    QLL               0
    QRATE             20
    MODE1DWELL        2.0
    MODE3ADWELL       0
    MODE3EDWELL       .24
    MODE4ADWELL       0
    MODE4EDWELL       0
    MODE5DWELL        1.0
    MODE3CPCDELTA     11.0
    MODE3DPCDELTA     101.0
    MODE4CPCDELTA     11.0
    MODE4DPCDELTA     101.0

    CHN
          SAMPLEWTS   0.05  0.05  0.1   0.2   0.6
          LOXGAIN     -0.02
          FUELGAIN    0
          LOXOFFST    0
          FUELOFFST   0
          TIMEGAIN    0
          TIMESTART   0
          TIMESTOP    0
          MODE0UL     105
          MODE0LL     0
          MODE1UL     3.0
          MODE1LL     3.0
          MODE1SD     3.0
          MODE1FACT   3.0
          MODE2UL     6.0
          MODE2LL     6.0
          MODE2FACT   3.0
          MODE3GAIN   4.539
          MODE3S1UL   12.0
          MODE3S1LL   12.0
          MODE3S2UL   12.0
          MODE3S2LL   12.0
          MODE3S3UL   12.0
          MODE3S3LL   12.0
          MODE4GAIN   -5.038
          MODE4S1UL   12.0
          MODE4S1LL   12.0
          MODE4S2UL   12.0
          MODE4S2LL   12.0
          MODE4S3UL   12.0
          MODE4S3LL   12.0
```

Table III
Adaptation Data for Pratt LOX Pump w/ Modified CCV Schedule

```
/* adaptation data using 10 samples from 904 MC for gains
   for PW LOX pump w/ modified CCV schedule */

COLIMIT 3     /* data for safd_4 algorithm */
RPL 3006.0    /* pcref at 100% */
GOXVALVE
   CLOSE        500.0  /* <time>*/

FUELVALVE
   CLOSE        500.0 /* <time>*/

LPOP_INLET_PR
   QUL          200.0
   QLL          0.0
   QRATE        120.0

LPFP_INLET_PR
   QUL          100.0
   QLL          0.0
   QRATE        60.0
```

```
PARAM     FPOV_POS  norm  CUTWEIGHT 1

    QUL               105.0
    QLL               0.0
    QRATE             20.0
    MODE1DWELL        2.0
    MODE3ADWELL       0
    MODE3EDWELL       .24
    MODE4ADWELL       0
    MODE4EDWELL       0
    MODE5DWELL        1.0
    MODE3CPCDELTA     100.0
    MODE3DPCDELTA     101.0
    MODE4CPCDELTA     100.0
    MODE4DPCDELTA     101.0

    CHN
          SAMPLEWTS   0.05  0.05  0.1   0.2   0.6
          LOXGAIN     0.01
          FUELGAIN    -.035
          LOXOFFST    0
          FUELOFFST   0
          TIMEGAIN    0
          TIMESTART   0
          TIMESTOP    0
          MODE0UL     105.0
          MODE0LL     0.0
          MODE1UL     1.4
          MODE1LL     1.4
          MODE1SD     1.4
          MODE1FACT   3.0
          MODE2UL     2.0
          MODE2LL     2.0
          MODE2FACT   3.0
          MODE3GAIN   3.1
          MODE3S1UL   6.5
          MODE3S1LL   6.5
          MODE3S2UL   6.5
          MODE3S2LL   6.5
          MODE3S3UL   6.5
          MODE3S3LL   6.5
          MODE4GAIN   -2.8
          MODE4S1UL   6.5
          MODE4S1LL   6.5
          MODE4S2UL   6.5
          MODE4S2LL   6.5
          MODE4S3UL   6.5
          MODE4S3LL   6.5
```

```
PARAM     FUEL_FLOW  norm  CUTWEIGHT 1

    QUL                  24000
    QLL                  0
    QRATE                14400
    MODE1DWELL           2.0
    MODE3ADWELL          0.28
    MODE3EDWELL          0.12
    MODE4ADWELL          0.28
    MODE4EDWELL          0.12
    MODE5DWELL           0.2
    MODE3CPCDELTA        11.0
    MODE3DPCDELTA        101.0
    MODE4CPCDELTA        11.0
    MODE4DPCDELTA        101.0

    CHN
          SAMPLEWTS      0.05   0.05   0.1    0.2    0.6
          LOXGAIN        0
          FUELGAIN       -2.3
          LOXOFFST       0
          FUELOFFST      0
          TIMEGAIN       0
          TIMESTART      0
          TIMESTOP       0
          MODE0UL        24000
          MODE0LL        0
          MODE1UL        250
          MODE1LL        250
          MODE1SD        250
          MODE1FACT      3.0
          MODE2UL        350
          MODE2LL        350
          MODE2FACT      3.0
          MODE3GAIN      1554
          MODE3S1UL      1000
          MODE3S1LL      1000
          MODE3S2UL      1000
          MODE3S2LL      1000
          MODE3S3UL      1000
          MODE3S3LL      1000
          MODE4GAIN      -1533
          MODE4S1UL      1000
          MODE4S1LL      1000
          MODE4S2UL      1000
          MODE4S2LL      1000
          MODE4S3UL      1000
          MODE4S3LL      1000
```

```
/*PARAM  HEX_BYPASS_MIX_INTERFACE_TEMP  norm  CUTWEIGHT 1

    QUL                 500
    QLL                 -300
    QRATE               480
    MODE1DWELL          2.0
    MODE3ADWELL         0.24
    MODE3EDWELL         0.24
    MODE4ADWELL         0.24
    MODE4EDWELL         0.24
    MODE5DWELL          0.2
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       101.0

    CHN
         SAMPLEWTS      0.05   0.05   0.1    0.2    0.6
         LOXGAIN        -1.0
         FUELGAIN       0
         LOXOFFST       0
         FUELOFFST      0
         TIMEGAIN       0
         TIMESTART      0
         TIMESTOP       0
         MODE0UL        500
         MODE0LL        -300
         MODE1UL        40.0
         MODE1LL        50.0
         MODE1SD        0
         MODE1FACT      3.0
         MODE2UL        40.0
         MODE2LL        50.0
         MODE2FACT      3.0
         MODE3GAIN      0
         MODE3S1UL      0
         MODE3S1LL      0
         MODE3S2UL      0
         MODE3S2LL      0
         MODE3S3UL      0
         MODE3S3LL      0
         MODE4GAIN      0
         MODE4S1UL      0
         MODE4S1LL      0
         MODE4S2UL      0
         MODE4S2LL      0
         MODE4S3UL      0
         MODE4S3LL      0
```

```
*/
/*PARAM   HEX_VENTURI_DELTA_PRESSURE   norm CUTWEIGHT 1

   QUL                 500
   QLL                 -500
   QRATE               600
   MODE1DWELL          2.0
   MODE3ADWELL         0.24
   MODE3EDWELL         0.24
   MODE4ADWELL         0.24
   MODE4EDWELL         0.24
   MODE5DWELL          0.2
   MODE3CPCDELTA       100.0
   MODE3DPCDELTA       101.0
   MODE4CPCDELTA       100.0
   MODE4DPCDELTA       101.0

   CHN
         SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
         LOXGAIN       -0.07
         FUELGAIN      0
         LOXOFFST      0
         FUELOFFST     0
         TIMEGAIN      0
         TIMESTART     0
         TIMESTOP      0
         MODE0UL       500.0
         MODE0LL       -500.0
         MODE1UL       5.0
         MODE1LL       5.0
         MODE1SD       0
         MODE1FACT     3.0
         MODE2UL       5.0
         MODE2LL       5.0
         MODE2FACT     3.0
         MODE3GAIN     0
         MODE3S1UL     0
         MODE3S1LL     0
         MODE3S2UL     0
         MODE3S2LL     0
         MODE3S3UL     0
         MODE3S3LL     0
         MODE4GAIN     0
         MODE4S1UL     0
         MODE4S1LL     0
         MODE4S2UL     0
         MODE4S2LL     0
         MODE4S3UL     0
         MODE4S3LL     0
```

```
*/
PARAM   HPFTP_ACCEL  type2  CUTWEIGHT 1

    QUL                30
    QLL                0
    QRATE              18
    MODE1DWELL         2.0
    MODE3ADWELL        0.24
    MODE3EDWELL        0.24
    MODE4ADWELL        0.24
    MODE4EDWELL        0.24
    MODE5DWELL         0.2
    MODE3CPCDELTA      100.0
    MODE3DPCDELTA      101.0
    MODE4CPCDELTA      100.0
    MODE4DPCDELTA      100.0

    CHN
          SAMPLEWTS    0.05  0.05  0.1   0.2   0.6
          LOXGAIN      0
          FUELGAIN     0
          LOXOFFST     0
          FUELOFFST    0
          PCREFLMTS    65    8.0   0
                       90    8.5   0
                       100   9.0   0
                       104   9.5   0
                       109   10.0  0
                       111   10.0  0
```

```
PARAM     HPFTP_BALANCE_CAVITY_PRESSURE  norm CUTWEIGHT 1

   QUL                  10000
   QLL                  0
   QRATE                4000
   MODE1DWELL           2.0
   MODE3ADWELL          0.28
   MODE3EDWELL          0.48
   MODE4ADWELL          0.28
   MODE4EDWELL          0.24
   MODE5DWELL           1.0
   MODE3CPCDELTA        10.0
   MODE3DPCDELTA        11.0
   MODE4CPCDELTA        10.0
   MODE4DPCDELTA        11.0

   CHN
         SAMPLEWTS      0.05   0.05   0.1   0.2   0.6
         LOXGAIN        0
         FUELGAIN       0
         LOXOFFST       0
         FUELOFFST      0
         TIMEGAIN       0
         TIMESTART      0
         TIMESTOP       0
         MODE0UL        10000.0
         MODE0LL        0
         MODE1UL        100
         MODE1LL        100
         MODE1SD        50
         MODE1FACT      3.0
         MODE2UL        100
         MODE2LL        100
         MODE2FACT      3.0
         MODE3GAIN      461
         MODE3S1UL      300
         MODE3S1LL      300
         MODE3S2UL      300
         MODE3S2LL      300
         MODE3S3UL      300
         MODE3S3LL      300
         MODE4GAIN      -471
         MODE4S1UL      300
         MODE4S1LL      300
         MODE4S2UL      300
         MODE4S2LL      300
         MODE4S3UL      300
         MODE4S3LL      300
```

```
PARAM     HPFTP_COOLANT_LINER_PRESSURE   norm   CUTWEIGHT 1

    QUL               7000
    QLL               1800
    QRATE             4200
    MODE1DWELL        2.0
    MODE3ADWELL       0.24
    MODE3EDWELL       0.48
    MODE4ADWELL       0.24
    MODE4EDWELL       0.24
    MODE5DWELL        1.0
    MODE3CPCDELTA     11.0
    MODE3DPCDELTA     26.0
    MODE4CPCDELTA     11.0
    MODE4DPCDELTA     26.0

    CHN
          SAMPLEWTS   0.05   0.05   0.1   0.2   0.6
          LOXGAIN     0
          FUELGAIN    0
          LOXOFFST    0
          FUELOFFST   0
          TIMEGAIN    0
          TIMESTART   0
          TIMESTOP    0
          MODE0UL     7000
          MODE0LL     1800
          MODE1UL     75
          MODE1LL     75
          MODE1SD     75
          MODE1FACT   3.0
          MODE2UL     60
          MODE2LL     60
          MODE2FACT   3.0
          MODE3GAIN   325
          MODE3S1UL   95
          MODE3S1LL   500
          MODE3S2UL   500
          MODE3S2LL   500
          MODE3S3UL   500
          MODE3S3LL   500
          MODE4GAIN   -334
          MODE4S1UL   500
          MODE4S1LL   500
          MODE4S2UL   500
          MODE4S2LL   500
          MODE4S3UL   500
          MODE4S3LL   500
```

PARAM HPFTP_DISCHARGE_PRESSURE norm CUTWEIGHT 1

QUL	9500
QLL	0
QRATE	5700
MODE1DWELL	2.0
MODE3ADWELL	0.28
MODE3EDWELL	0.36
MODE4ADWELL	0.36
MODE4EDWELL	0.24
MODE5DWELL	1.0
MODE3CPCDELTA	100.0
MODE3DPCDELTA	101.0
MODE4CPCDELTA	100.0
MODE4DPCDELTA	101.0

CHN

SAMPLEWTS	0.05	0.05	0.1	0.2	0.6
LOXGAIN	-0.25				
FUELGAIN	-0.6				
LOXOFFST	0				
FUELOFFST	0				
TIMEGAIN	0				
TIMESTART	0				
TIMESTOP	0				
MODE0UL	9500				
MODE0LL	0				
MODE1UL	150				
MODE1LL	150				
MODE1SD	150				
MODE1FACT	3.0				
MODE2UL	80				
MODE2LL	80				
MODE2FACT	3.0				
MODE3GAIN	574				
MODE3S1UL	850				
MODE3S1LL	850				
MODE3S2UL	850				
MODE3S2LL	850				
MODE3S3UL	850				
MODE3S3LL	850				
MODE4GAIN	-586				
MODE4S1UL	850				
MODE4S1LL	850				
MODE4S2UL	850				
MODE4S2LL	850				
MODE4S3UL	850				
MODE4S3LL	850				

```
PARAM    HPFTP_SHAFT_SPEED norm  OUTWEIGHT 1

    QUL                45000
    QLL                0
    QRATE              27000
    MODE1DWELL         2.0
    MODE3ADWELL        0.24
    MODE3EDWELL        0.24
    MODE4ADWELL        0.24
    MODE4EDWELL        0.24
    MODE5DWELL         1.0
    MODE3CPCDELTA      100.0
    MODE3DPCDELTA      101.0
    MODE4CPCDELTA      100.0
    MODE4DPCDELTA      101.0

    CHN
          SAMPLEWTS    0.05   0.05   0.1    0.2    0.6
          LOXGAIN      0
          FUELGAIN     -4.9
          LOXOFFST     0
          FUELOFFST    0
          TIMEGAIN     0
          TIMESTART    0
          TIMESTOP     0
          MODE0UL      45000
          MODE0LL      0
          MODE1UL      400
          MODE1LL      400
          MODE1SD      400
          MODE1FACT    3.0
          MODE2UL      300
          MODE2LL      300
          MODE2FACT    3.0
          MODE3GAIN    2076
          MODE3S1UL    2500
          MODE3S1LL    2500
          MODE3S2UL    2500
          MODE3S2LL    2500
          MODE3S3UL    2500
          MODE3S3LL    2500
          MODE4GAIN    -2088
          MODE4S1UL    2500
          MODE4S1LL    2500
          MODE4S2UL    2500
          MODE4S2LL    2500
          MODE4S3UL    2500
          MODE4S3LL    2500
```

```
PARAM     HPFTP_TURBINE_DIS_TEMP_CH_A  norm CUTWEIGHT 1

   QUL              2650
   QLL              810
   QRATE            500
   MODE1DWELL       2.0
   MODE3ADWELL      0.24
   MODE3EDWELL      0.24
   MODE4ADWELL      0.24
   MODE4EDWELL      0.24
   MODE5DWELL       1.0
   MODE3CPCDELTA    100.0
   MODE3DPCDELTA    101.0
   MODE4CPCDELTA    100.0
   MODE4DPCDELTA    101.0

   CHN
         SAMPLEWTS  0.05  0.05  0.1   0.2   0.6
         LOXGAIN    0.0
         FUELGAIN   -0.4
         LOXOFFST   0
         FUELOFFST  0
         TIMEGAIN   0
         TIMESTART  0
         TIMESTOP   0
         MODE0UL    2650
         MODE0LL    810
         MODE1UL    50
         MODE1LL    50
         MODE1SD    50
         MODE1FACT  3.0
         MODE2UL    60
         MODE2LL    60
         MODE2FACT  3.0
         MODE3GAIN  55
         MODE3S1UL  200
         MODE3S1LL  200
         MODE3S2UL  200
         MODE3S2LL  200
         MODE3S3UL  200
         MODE3S3LL  200
         MODE4GAIN  -55
         MODE4S1UL  200
         MODE4S1LL  200
         MODE4S2UL  200
         MODE4S2LL  200
         MODE4S3UL  200
         MODE4S3LL  200
```

PARAM HPFTP_TURBINE_DIS_TEMP_CH_B norm CUTWEIGHT 1

QUL	2650
QLL	810
QRATE	500
MODE1DWELL	2.0
MODE3ADWELL	0.24
MODE3EDWELL	0.24
MODE4ADWELL	0.24
MODE4EDWELL	0.24
MODE5DWELL	1.0
MODE3CPCDELTA	11.0
MODE3DPCDELTA	26.0
MODE4CPCDELTA	11.0
MODE4DPCDELTA	26.0

CHN

SAMPLEWTS	0.05	0.05	0.1	0.2	0.6
LOXGAIN	0.0				
FUELGAIN	-0.4				
LOXOFFST	0				
FUELOFFST	0				
TIMEGAIN	0				
TIMESTART	0				
TIMESTOP	0				
MODE0UL	2650				
MODE0LL	810				
MODE1UL	50				
MODE1LL	50				
MODE1SD	50				
MODE1FACT	3.0				
MODE2UL	60				
MODE2LL	60				
MODE2FACT	3.0				
MODE3GAIN	37				
MODE3S1UL	200				
MODE3S1LL	200				
MODE3S2UL	200				
MODE3S2LL	200				
MODE3S3UL	200				
MODE3S3LL	200				
MODE4GAIN	-45				
MODE4S1UL	200				
MODE4S1LL	200				
MODE4S2UL	200				
MODE4S2LL	200				
MODE4S3UL	200				
MODE4S3LL	200				

```
PARAM    HPOTP_BOOST_PUMP_RADIAL_ACCEL  type2  CUTWEIGHT 1

   QUL                30
   QLL                0
   QRATE              18
   MODE1DWELL         2.0
   MODE3ADWELL        0.24
   MODE3EDWELL        0.24
   MODE4ADWELL        0.24
   MODE4EDWELL        0.24
   MODE5DWELL         0.2
   MODE3CPCDELTA      100.0
   MODE3DPCDELTA      101.0
   MODE4CPCDELTA      100.0
   MODE4DPCDELTA      101.0

   CHN
         SAMPLEWTS    0.05  0.05  0.1   0.2   0.6
         LOXGAIN      0
         FUELGAIN     0
         LOXOFFST     0
         FUELOFFST    0
         PCREFLMTS    65    5.5   0
                      90    7.0   0
                      100   8.0   0
                      104   9.0   0
                      109   9.5   0
                      111   9.5   0
```

```
PARAM    HPOTP_DISCHARGE_PRESSURE   norm   CUTWEIGHT   1

    QUL                 7000
    QLL                 0
    QRATE               3000
    MODE1DWELL          2.0
    MODE3ADWELL         0.24
    MODE3EDWELL         0.48
    MODE4ADWELL         0.34
    MODE4EDWELL         0.24
    MODE5DWELL          1.0
    MODE3CPCDELTA       16.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       16.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05   0.05   0.1   0.2   0.6
          LOXGAIN       0
          FUELGAIN      0
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       7000
          MODE0LL       0
          MODE1UL       140
          MODE1LL       140
          MODE1SD       140
          MODE1FACT     3.0
          MODE2UL       55
          MODE2LL       55
          MODE2FACT     3.0
          MODE3GAIN     441
          MODE3S1UL     450
          MODE3S1LL     450
          MODE3S2UL     450
          MODE3S2LL     450
          MODE3S3UL     450
          MODE3S3LL     450
          MODE4GAIN     -464
          MODE4S1UL     450
          MODE4S1LL     450
          MODE4S2UL     450
          MODE4S2LL     450
          MODE4S3UL     450
          MODE4S3LL     450
```

```
PARAM     HPOTP_IMSL_PURGE_PRESS  norm CUTWEIGHT 1

    QUL                 650
    QLL                 0
    QRATE               200
    MODE1DWELL          2.0
    MODE3ADWELL         0.24
    MODE3EDWELL         0.24
    MODE4ADWELL         0.24
    MODE4EDWELL         0.24
    MODE5DWELL          0.2
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05   0.05   0.1   0.2   0.6
          LOXGAIN       0
          FUELGAIN      0
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       650.0
          MODE0LL       0
          MODE1UL       5.0
          MODE1LL       5.0
          MODE1SD       5.0
          MODE1FACT     3.0
          MODE2UL       10.0
          MODE2LL       10.0
          MODE2FACT     10.0
          MODE3GAIN     1.7
          MODE3S1UL     22.0
          MODE3S1LL     22.0
          MODE3S2UL     22.0
          MODE3S2LL     22.0
          MODE3S3UL     22.0
          MODE3S3LL     22.0
          MODE4GAIN     -1.7
          MODE4S1UL     22.0
          MODE4S1LL     22.0
          MODE4S2UL     22.0
          MODE4S2LL     22.0
          MODE4S3UL     22.0
          MODE4S3LL     22.0
```

```
PARAM     HPOTP_BOOST_PUMP_DIS_PRESSURE   norm   CUTWEIGHT 1

  QUL                   9500
  QLL                   0
  QRATE                 4700
  MODE1DWELL            2.0
  MODE3ADWELL           0.24
  MODE3EDWELL           0.48
  MODE4ADWELL           0.24
  MODE4EDWELL           0.24
  MODE5DWELL            1.0
  MODE3CPCDELTA         16.0
  MODE3DPCDELTA         101.0
  MODE4CPCDELTA         16.0
  MODE4DPCDELTA         101.0

  CHN
        SAMPLEWTS       0.05   0.05   0.1   0.2   0.6
        LOXGAIN         -1.0
        FUELGAIN        0.5
        LOXOFFST        0
        FUELOFFST       0
        TIMEGAIN        0
        TIMESTART       0
        TIMESTOP        0
        MODE0UL         9500
        MODE0LL         0
        MODE1UL         90
        MODE1LL         90
        MODE1SD         90
        MODE1FACT       3.0
        MODE2UL         150
        MODE2LL         150
        MODE2FACT       3.0
        MODE3GAIN       772
        MODE3S1UL       1000
        MODE3S1LL       1000
        MODE3S2UL       1000
        MODE3S2LL       1000
        MODE3S3UL       1000
        MODE3S3LL       1000
        MODE4GAIN       -827
        MODE4S1UL       1000
        MODE4S1LL       1000
        MODE4S2UL       1000
        MODE4S2LL       1000
        MODE4S3UL       1000
        MODE4S3LL       1000
```

```
PARAM     HPOTP_SEC_SEAL_CAVITY_PR  type1  CUTWEIGHT 1

    QUL                 300
    QLL                 4
    QRATE               180
    MODE1DWELL          2.0
    MODE3ADWELL         0.24
    MODE3EDWELL         0.24
    MODE4ADWELL         0.24
    MODE4EDWELL         0.24
    MODE5DWELL          0.2
    MODE3CPCDELTA       16.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       16.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
          LOXGAIN       0
          FUELGAIN      0
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0.05575
          TIMESTART     7.0
          TIMESTOP      500.0
          MODE0UL       300
          MODE0LL       4
          MODE1UL       3.0
          MODE1LL       3.0
          MODE1SD       3.0
          MODE1FACT     3.0
          MODE2UL       10
          MODE2LL       10
          MODE2FACT     3.0
          MODE3GAIN     2.6
          MODE3S1UL     20.0
          MODE3S1LL     20.0
          MODE3S2UL     20.0
          MODE3S2LL     20.0
          MODE3S3UL     20.0
          MODE3S3LL     20.0
          MODE4GAIN     -2.3
          MODE4S1UL     20.0
          MODE4S1LL     20.0
          MODE4S2UL     20.0
          MODE4S2LL     20.0
          MODE4S3UL     20.0
          MODE4S3LL     20.0
```

```
PARAM     HPOTP_TURBINE_DIS_TEMP_CH_A    norm  CUTWEIGHT 1

    QUL                 2650
    QLL                 810
    QRATE               500
    MODE1DWELL          2.0
    MODE3ADWELL         0.84
    MODE3EDWELL         0.84
    MODE4ADWELL         0.84
    MODE4EDWELL         0.84
    MODE5DWELL          3.0
    MODE3CPCDELTA       100.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       100.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05   0.05   0.1    0.2    0.6
          LOXGAIN       -0.45
          FUELGAIN      1.2
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       2650
          MODE0LL       150
          MODE1UL       75
          MODE1LL       75
          MODE1SD       75
          MODE1FACT     3.0
          MODE2UL       100
          MODE2LL       100
          MODE2FACT     3.0
          MODE3GAIN     57
          MODE3S1UL     350
          MODE3S1LL     350
          MODE3S2UL     350
          MODE3S2LL     350
          MODE3S3UL     350
          MODE3S3LL     350
          MODE4GAIN     -50
          MODE4S1UL     350
          MODE4S1LL     350
          MODE4S2UL     350
          MODE4S2LL     350
          MODE4S3UL     350
          MODE4S3LL     350
```

```
PARAM     HPOTP_TURBINE_DIS_TEMP_CH_B  norm  CUTWEIGHT 1

    QUL               2650
    QLL               810
    QRATE             500
    MODE1DWELL        2.0
    MODE3ADWELL       0.84
    MODE3EDWELL       0.84
    MODE4ADWELL       0.84
    MODE4EDWELL       0.84
    MODE5DWELL        3.0
    MODE3CPCDELTA     100.0
    MODE3DPCDELTA     101.0
    MODE4CPCDELTA     100.0
    MODE4DPCDELTA     101.0

    CHN
          SAMPLEWTS   0.05  0.05  0.1   0.2   0.6
          LOXGAIN     -0.45
          FUELGAIN    1.2
          LOXOFFST    0
          FUELOFFST   0
          TIMEGAIN    0
          TIMESTART   0
          TIMESTOP    0
          MODE0UL     2650
          MODE0LL     150
          MODE1UL     75
          MODE1LL     75
          MODE1SD     75
          MODE1FACT   3.0
          MODE2UL     100
          MODE2LL     100
          MODE2FACT   3.0
          MODE3GAIN   60
          MODE3S1UL   350
          MODE3S1LL   350
          MODE3S2UL   350
          MODE3S2LL   350
          MODE3S3UL   350
          MODE3S3LL   350
          MODE4GAIN   -60
          MODE4S1UL   350
          MODE4S1LL   350
          MODE4S2UL   350
          MODE4S2LL   350
          MODE4S3UL   350
          MODE4S3LL   350
```

```
PARAM     LPFTP_SHAFT_SPEED  norm CUTWEIGHT 1

    QUL                 20000
    QLL                 0
    QRATE               12000
    MODE1DWELL          2.0
    MODE3ADWELL         0.36
    MODE3EDWELL         0.48
    MODE4ADWELL         0.36
    MODE4EDWELL         0.24
    MODE5DWELL          1.0
    MODE3CPCDELTA       16.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       16.0
    MODE4DPCDELTA       101.0

    CHN
            SAMPLEWTS   0.05   0.05   0.1   0.2   0.6
            LOXGAIN     -0.7
            FUELGAIN    -2.8
            LOXOFFST    0
            FUELOFFST   0
            TIMEGAIN    0
            TIMESTART   0
            TIMESTOP    0
            MODE0UL     20000
            MODE0LL     0
            MODE1UL     225
            MODE1LL     225
            MODE1SD     225
            MODE1FACT   3.0
            MODE2UL     225
            MODE2LL     225
            MODE2FACT   3.0
            MODE3GAIN   570
            MODE3S1UL   1100
            MODE3S1LL   1100
            MODE3S2UL   1100
            MODE3S2LL   1100
            MODE3S3UL   1100
            MODE3S3LL   1100
            MODE4GAIN   -572
            MODE4S1UL   1100
            MODE4S1LL   1100
            MODE4S2UL   1100
            MODE4S2LL   1100
            MODE4S3UL   1100
            MODE4S3LL   1100
```

```
PARAM     LPOTP_PUMP_DISCHARGE_PRESSURE  norm  CUTWEIGHT 1

    QUL              600
    QLL              0
    QRATE            200
    MODE1DWELL       2.0
    MODE3ADWELL      0.24
    MODE3EDWELL      0.24
    MODE4ADWELL      0.44
    MODE4EDWELL      0.24
    MODE5DWELL       0.4
    MODE3CPCDELTA    100.0
    MODE3DPCDELTA    101.0
    MODE4CPCDELTA    100.0
    MODE4DPCDELTA    101.0

    CHN
          SAMPLEWTS  0.05   0.05   0.1   0.2   0.6
          LOXGAIN    0.85
          FUELGAIN   0
          LOXOFFST   0
          FUELOFFST  0
          TIMEGAIN   0
          TIMESTART  0
          TIMESTOP   0
          MODE0UL    600
          MODE0LL    0
          MODE1UL    10.0
          MODE1LL    10.0
          MODE1SD    10.0
          MODE1FACT  3.0
          MODE2UL    10.0
          MODE2LL    10.0
          MODE2FACT  3.0
          MODE3GAIN  18
          MODE3S1UL  40.0
          MODE3S1LL  40.0
          MODE3S2UL  40.0
          MODE3S2LL  40.0
          MODE3S3UL  40.0
          MODE3S3LL  40.0
          MODE4GAIN  -17
          MODE4S1UL  40.0
          MODE4S1LL  40.0
          MODE4S2UL  40.0
          MODE4S2LL  40.0
          MODE4S3UL  40.0
          MODE4S3LL  40.0
```

```
PARAM     MCC_PRESSURE  norm  CUTWEIGHT  1

    QUL                3500
    QLL                0
    QRATE              2100
    MODE1DWELL         2.0
    MODE3ADWELL        0.24
    MODE3EDWELL        0.48
    MODE4ADWELL        0.14
    MODE4EDWELL        0.24
    MODE5DWELL         0.6
    MODE3CPCDELTA      9.0
    MODE3DPCDELTA      26.0
    MODE4CPCDELTA      9.0
    MODE4DPCDELTA      26.0

    CHN
          SAMPLEWTS    0.05  0.05  0.1  0.2  0.6
          LOXGAIN      0
          FUELGAIN     0
          LOXOFFST     0
          FUELOFFST    0
          TIMEGAIN     0
          TIMESTART    0
          TIMESTOP     0
          MODE0UL      3500
          MODE0LL      0
          MODE1UL      60
          MODE1LL      60
          MODE1SD      60
          MODE1FACT    3.0
          MODE2UL      30
          MODE2LL      30
          MODE2FACT    3.0
          MODE3GAIN    300
          MODE3S1UL    350
          MODE3S1LL    350
          MODE3S2UL    350
          MODE3S2LL    350
          MODE3S3UL    350
          MODE3S3LL    350
          MODE4GAIN    -300
          MODE4S1UL    350
          MODE4S1LL    350
          MODE4S2UL    350
          MODE4S2LL    350
          MODE4S3UL    350
          MODE4S3LL    350
```

```
PARAM     MCC_LINER_CAVITY_PRESSURE type1   CUTWEIGHT 1

    QUL                    100
    QLL                    -100
    QRATE                  120
    MODE1DWELL             2.0
    MODE3ADWELL            0.24
    MODE3EDWELL            0.24
    MODE4ADWELL            0.24
    MODE4EDWELL            0.24
    MODE5DWELL             0.2
    MODE3CPCDELTA          100.0
    MODE3DPCDELTA          101.0
    MODE4CPCDELTA          100.0
    MODE4DPCDELTA          101.0

    CHN
           SAMPLEWTS       0.05   0.05   0.1    0.2    0.6
           LOXGAIN         0
           FUELGAIN        0
           LOXOFFST        0
           FUELOFFST       0
           TIMEGAIN        0
           TIMESTART       0
           TIMESTOP        0
           MODE0UL         100.0
           MODE0LL         -100.0
           MODE1UL         3.3
           MODE1LL         0.6
           MODE1SD         3.3
           MODE1FACT       3.0
           MODE2UL         3.3
           MODE2LL         0.6
           MODE2FACT       3.0
           MODE3GAIN       0
           MODE3S1UL       3.3
           MODE3S1LL       3.3
           MODE3S2UL       3.3
           MODE3S2LL       3.3
           MODE3S3UL       3.3
           MODE3S3LL       3.3
           MODE4GAIN       0
           MODE4S1UL       3.3
           MODE4S1LL       3.3
           MODE4S2UL       3.3
           MODE4S2LL       3.3
           MODE4S3UL       3.3
           MODE4S3LL       3.3
```

```
PARAM     OPOV_ACT_POSITION  norm  OUTWEIGHT 1

    QUL                 105
    QLL                 0
    QRATE               20
    MODE1DWELL          2.0
    MODE3ADWELL         0
    MODE3EDWELL         .24
    MODE4ADWELL         0
    MODE4EDWELL         0
    MODE5DWELL          1.0
    MODE3CPCDELTA       11.0
    MODE3DPCDELTA       101.0
    MODE4CPCDELTA       11.0
    MODE4DPCDELTA       101.0

    CHN
          SAMPLEWTS     0.05  0.05  0.1   0.2   0.6
          LOXGAIN       -0.02
          FUELGAIN      0
          LOXOFFST      0
          FUELOFFST     0
          TIMEGAIN      0
          TIMESTART     0
          TIMESTOP      0
          MODE0UL       105
          MODE0LL       0
          MODE1UL       3.0
          MODE1LL       3.0
          MODE1SD       3.0
          MODE1FACT     3.0
          MODE2UL       6.0
          MODE2LL       6.0
          MODE2FACT     3.0
          MODE3GAIN     3.5
          MODE3S1UL     12.0
          MODE3S1LL     12.0
          MODE3S2UL     12.0
          MODE3S2LL     12.0
          MODE3S3UL     12.0
          MODE3S3LL     12.0
          MODE4GAIN     -3.6
          MODE4S1UL     12.0
          MODE4S1LL     12.0
          MODE4S2UL     12.0
          MODE4S2LL     12.0
          MODE4S3UL     12.0
          MODE4S3LL     12.0
```

Table IV
Significant Failures

Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	HPFP Dis Pr	HPFP Sh Sp	HPFP TDT A	HPFP TDT B	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos	Notes
														Significant Failures															
750-041	4.30												M							M	M								SD in Start
750-148	16.00										C	M		C	D	D		D		C		D	D				M		
750-160	3.14											M																	SD in Start
750-175	115.60						115.60				C	C	C		D		C	C		C		D	D		C				
750-259	101.50						101.38		C		C	C	C		C			C	C	M		C		C	C		CD		
750-285	223.54																D												
901-110	0.00	C																											Missing TREF
901-133	1541.76			M						M		M					M				M								TREF Bad/Miss PCRef
901-136	0.00	C																											Missing TREF
901-147	0.00	C																											Missing TREF
901-173	201.16											C	D		D	D		D		M	M		D	C		C			
901-183	51.06									C	C		M							M	M						M		
901-222	9.98			M	M	M				M	M	M			M	M	M				M	M	M				M		Missing Pc Ref
901-225	255.50											M							C	M	M	C					M		
901-284	9.70						C					M	D			D		D	D	M	D	D	D		D	C			Cut by Analysis
901-331	233.04						232.48	C	C	C		M	C		D	D		C		D		C	C	C	C	C			
901-364	392.16						386.20	D	C	CD	CD	M	D	C	C	C	D	C		D		D	D	D	D	C		D	
901-436	611.04						610.92	C	C		C	C	C		C	C			C	M		C	C			C			
901-468	203.88											C																	
901-666	4.28																												SD in Start
902-120	4.82											M	M					M	M		M	M	M				M		SD in Start
902-132	2.32											M									M						M		SD in Start
902-198	8.44											M																	
902-249	450.58						378.54	C	C	CD		C	C	C	CD	CD		C		C				C					
902-428	204.00																												
902-471	147.66																						C						
902-562	1.24																												SD in Start
904-044	1270.70											C						C											
904-145	241.10						241.06						C					C		C									Pratt LOX Pump
904-149	109.82																C												Pratt LOX Pump
SF0601A																													No Data
SF0603B																													No Data
SF1001C																													No Data

Table V Other Failures

Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	HPFP Dis Pr	HPFP Sh Sp (Other Failures)	HPFP TDT A (Other Failures)	HPFP TDT B (Other Failures)	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos	Notes
750-189	9.98				M	M				M	M	M					M			M							M		
750-194	16.82									D	M	D								M									
750-245	25.58									C										M									
	0.00	C																											TREF Missing
901-189	64.60			M	M	M		M		M	M	M	M		M	M	M	M	M	M	M	M	M				M		Parameters Missing
	0.00	C																											TREF Missing
901-353	424.08						389.80	C		C	C				D	D				M									
901-421	148.48						76.40	C		C				C		C	M			M		C	C						
901-485	28.46																												
901-501	519.10																			M									
901-577	84.10						80.62	C	C		C		C							C		C	C	C					
901-578	596.36						581.24	C														C	C						
901-600	288.60																										M		
901-674	3.68																												SD in Start
901-694	369.18																			M									
902-095	1634.56									M		C			D		D	D		M	M		D						
	0.00	C																											TREF Missing
902-118	9.66												M		M	M		M	M	M	M	M	M				M		
902-145	68.58									C		M			M	M				M	M	M	M				M		
902-157	90.40											M								M	C				C		M		
902-158	27.62											M			M	M				M	C	M	M				M		
902-162	9.76											M								M							M		
902-297	23.36									C										M									
902-302	215.34											C								M									
902-330	10.06																M			M									
904-029	14.18																												
904-055	205.98									D							D		C				C				D		
904-146	46.60																M			M									
TTB-022	9.98																			M									

Table VI
Good Tests
Rkdn Eng/ Nominal CCV

RD Engine/Nominal CCV

Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	HPFP Dis Pr	HPFP Sh Sp	HPFP TDT A	HPFP TDT B	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos	Notes
750-168	299.96										C	M															M		Param bad
750-280	199.96																												
750-281	199.94																												
750-282	199.94																												
750-283	299.94																												
750-284	299.94																												
750-285	223.54																D												
750-286	299.94																												
750-288	4.34																												SD in Start
750-289	299.96									D							D										D		
750-290	299.88															D				D			D						
750-291	299.82											D	D	D	D			D	D		D	D		D	D	C			Ch A failed
750-292	99.96																												
750-294	99.96						C	C	C		C	C	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C	Pc Ref bad
750-295	99.94							D				D	M																
750-296	99.94																												
750-297	99.96																												
750-298	149.94																												
750-299	209.98																												
750-300	5.98																												SD in Start
750-301	279.96																												
750-308	279.96																												
750-310	10.08																												
750-311	299.96																												
750-313	1.46																												SD in Start
750-316	1.48																												SD in Start
750-319	299.96																												
750-320	289.94																												

Table VI
Good Tests
Rkdn Eng/ Nominal CCV

															RD Engine/Nominal CCV													
Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	HPFP Dis Pr	HPFP Sh Sp	HPFP TDT A	HPFP TDT B	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos	Notes
901-307	75						C					M			C	C									C		M		Possible failure?
901-346	499.92							C				M					D							C			C		
901-433	699.94				M	M		D	D	M	M	M	D	D	D	D	M			M		D	D	D	D		M	D	disq for missing inlets
901-539	299.96																			M									
901-550	249.96																			M									
901-571	519.9																												
901-579	599.94						C	D	C		C		D	C				C		D		D	D	D	D			D	MXRT shift
901-582	49.98																			M									
901-591	760.92																												
901-606	299.96																			M									
901-617	79.9																			M									
901-623	264.86																			M									
901-631	299.84																			M									
901-636	174.88									D										M									
901-643	299.96																			M									
901-652	149.96																			M									
901-655	639.9									C		D	D	D	D			D	D		D	D		D	D				
901-660	0	C																											Missing TREF
901-661	99.96																			M									
901-662	77						C	C	C	D	C	CD	C	C	CD	CD		C		M		D	D	C	C	C		CD	OK - PC Ref bad @ 75
901-663	99.96																												
901-667	299.98																												
901-668	549.96																												
901-669	512.92																												
901-672	299.98																			M									
901-713	49.96																			M									
901-721	24.96																			M									

Table VI
Good Tests
Rkdn Eng/ Nominal CCV

													RD Engine/Nominal CCV																
Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	HPFP Dis Pr	HPFP Sh Sp	HPFP TDT A	HPFP TDT B	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos	Notes
902-248	499.94											C							C	M									
902-391	249.96									M							M			M									
902-405	199.96									M							M			M									
902-430	249.94																			M									
902-495	299.84																										M		
902-503	79.98																			M									
902-570	79.92																												
902-571	299.82																												
902-572	299.82																												
902-573	549.72																												
902-574	299.84																												
902-575	299.84																												
902-576	299.84																												
902-577	79.94																												
902-578	299.82																												
902-579	299.84																												
902-580	299.84																												
902-581	299.82																												
902-582	299.84																												
902-583	299.86																												
902-584	299.84																												
902-585	299.84														D	D						D	D						
902-586	299.84																					D	D						
902-587	299.82										C											D	D						
902-588	299.84																					D	D						
902-589	299.82																					D	D						
902-590	299.84																					D	D						
902-591	299.84																					D	D						
902-592	299.82																												
902-593	299.84																												
902-594	299.82																												
902-595	299.82																												
902-596	259.84																			C									
902-597	299.84																												
902-598	299.84																												
902-599	299.82										D																		
902-600	339.82																												
904-003	219.98																			M									
904-128	174.96																												
904-134	44.96																												

Table VII
Good Tests
PW LOX / Nominal CCV

PW LOX, Nominal CCV

Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	HPFP Dis Pr	HPFP Sh Sp	HPFP TDT A	HPFP TDT B	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos	Notes
901-721	24.96																												
901-728	71.84																												Fac. Delta T Cut
901-729	100.68																												Fac. Delta T Cut
901-730	195.62																												Fac. Delta T Cut
901-731	849.98																												
901-732	136.46																D												Fac. Cut for Fire
901-733	519.96																												
901-734	849.98																												
901-735	519.94																												
901-736	849.96														D	D													
901-737	849.96														D	D													
901-738	14.98														D	D													
901-739	14.96														D														
901-795	199.98																												
904-150	519.96																												
904-151	519.94																												
904-152	519.94																												
904-153	519.94																												
904-154	519.94																												
904-155	79.80																												
904-156	210.18																												Fac. Delta T Cut
904-157	166.00																												Fac. Delta T Cut
904-158	519.98																												
904-159	187.86																												Fac. Delta T Cut
904-160	519.98																												
904-161	293.80																												
904-162	519.94																				C								
904-163	519.96														D														
904-164	753.98																												
904-165	502.98																				C								
904-166	258.60																												Fac. Delta T Cut
904-167	753.94																												
904-168	39.96																												
904-169	753.96																												
904-170	849.96																												
904-171	859.96							C																					
904-172	849.94							C																					
904-173	849.98							C																					
904-174	218.92																				C								IMSL Lo RL Cut
904-175	519.94														D	D													
904-176	73.52														D	D													Fac Cut for Fire
904-177	519.96														D	D													
904-178	264.98														D	D													ELU Induced
904-179	519.96														D	D													
904-180	849.96									C					D	D													Thrust Limiting
904-181	519.98							D	D	D	D		D	D	D	D	D			D		D	D	D	D		CD	D	Bad data

Table VIII
Good Tests
PW LOX/Modified CCV

Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	PW LOX, Modified CCV HPFP Dis Pr	HPFP Sh Sp	HPFP TDT A	HPFP TDT B	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos	
901-716	519.96																												FID 7-300 FS Failed On
901-717	519.94																												FID 10-300 FS Failed On
901-718	519.98																												
901-719	519.96																												
901-720	519.96																												
901-722	519.96				D																								
901-723	753.90														C				C							C			DCUA Halted in MS
901-724	9.96																												RD engine
901-725	9.96																												RD engine
901-726	9.96																D												RD engine
901-727	1.66																												SD in Start
901-763	760.98														D	D						D	D						Thrust Limiting
901-764	519.98														D	D						D	D						
901-765	753.96														D	D						D	D						
901-766	548.44														D	D						D	D						
901-767	753.98														D	D						D	D						
901-768	753.94														D	D						D	D						
901-769	753.86																			D									Ch B pwr off in MS
901-770	199.94												D																IEB fail / RD eng
901-771	753.88												D																DCUA halt/hyd pwr off
901-772	854.94																		C										OEA fail in MS
901-773	519.94																												OEB fail in MS
901-774	519.94																				D								IEA fail in MS
901-775	1.98														D	D						D	D						SD in start
901-776	519.96																				D								DCUB halt
901-777	709.82											D	D	D				D	D		D			D	D				DCUA pwr off in MS
901-778	502.94																				D								
901-779	760.94																				D								
901-780	519.96																												
901-781	753.94																												
901-782	519.96																				D								
901-783	209.96																												
901-784	209.96																												
901-785	519.96																				D								FID 117 - V1A
901-786	519.94																				D								
901-787	519.94																												
901-788	760.94																				D								
901-789	502.94									C											D								
901-790	519.96																				D								
901-791	753.94																				D								
901-792	249.94																												
901-793	709.96																				D								
901-794	209.98																				D								
901-796	77.70											D																	Fire - PW Fuel? pump
901-800	519.98																D												
901-806	753.98																				D								
901-807	519.98																												
901-808	209.98																												
901-809	760.98									C											D								
901-810	214.98																												

Table VIII
Good Tests
PW LOX/Modified CCV

													PW LOX, Modified CCV																
Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	HPFP Dis Pr	HPFP Sh Sp	HPFP TDT A	HPFP TDT B	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos	
901-811	519.98																												
901-812	502.94																												
901-813	519.96																												
901-814	519.98																				D								
901-815	519.96																												
901-816	209.96												C										C						
901-817	299.96																												

Table VIII
Good Tests
PW LOX/ Modified CCV

PW LOX, Modified CCV

Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	HPFP Dis Pr	HPFP Sh Sp	HPFP TDT A	HPFP TDT B	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos	
904-182	14.96																												Bomb Test
904-183	14.98																												Bomb Test
904-184	14.96																												Bomb Test
904-185	704.96																												
904-186	299.96																												
904-187	124.90															D							D						DCUB Pwr Off - ELU
904-188	519.98																												
904-189	254.94																												
904-190	184.98																												
904-191	184.98														D	D						D	D						
904-192	254.96														D	D						D	D						
904-193	519.94														D	D						D	D						
904-194	519.96														D	D						D	D						
904-195	529.96														D	D						D	D						
904-196	753.90														D	D						D	D	C					Hyd Pr Off in MS
904-197	519.94														D	D						D	D						
904-198	502.94														D	D						D	D						
904-199	6.22														D	D						D	D						SD Prior to SAFD
904-200	709.96																												
904-201	599.96														C														
904-202	502.96														D	D						D	D						FF Failures Induced
904-203	519.96																												
904-204	519.96																												
904-205	519.96														C														
904-206	437.96																												
904-207	519.94														C						C								
904-208	519.98																M										D		
904-209	519.94																												
904-210	709.94												D																
904-211	502.96												D																
904-212	519.96												D																
904-213	753.82											D	D	D				D	D		D			D	D				Ch A Pwr Off in MS
904-214	502.96																												ELU in MS
904-215	760.94																												OEA fail in MS
904-216	753.92																												DCUB halt
904-217	87.36																												fire in POGO area
904-218	753.90																												HLU in MS
904-219	502.94														C														IEA fail in MS
904-220	760.94														C														OEB fail in MS
904-226	219.94																												IEA fail in MS
904-227	219.94											C																	IEA fail in MS
904-228	299.98						C		C		C	C	C	C	C	C		C		C		C	C	C	C	C			Ctl stability test
904-233	519.94						C	C	C				C	C								C	C						MR mods @ 454
904-234	665.92						C	C	C		C		C	C	C			C		C		C	C	C				C	MR mods @ 80/HPOP TDT A
904-235	219.94														C														HPOP TDT A/HLU
904-236	519.94															C													
904-237	519.94														D	D					D								
904-238	519.96														D	D													
904-239	709.96														D	D					D								
904-240	519.96														D	D													
904-241	753.96														D	D													

Table VIII
Good Tests
PW LOX/ Modified CCV

													PW LOX, Modified CCV															
Test	SD	TREF	Eng Stat	Pc Ref	LPOP In Pr	LPFP In Pr	C/O	FPOV Pos	Fuel Flow	HPFP Accel	HPFP Bal Cav Pr	HPFP Clnt Lin Pr	HPFP Dis Pr	HPFP Sh Sp	HPFP TDT A	HPFP TDT B	HPOP Acc	HPOP Dis Pr	HPOP IMSL	HPOP PBP Dis Pr	HPOP SSC Pr	HPOP TDT A	HPOP TDT B	LPFP Sh Sp	LPOP Dis Pr	MCC Pc	MCC Lin Cav Pr	OPOV Pos
904-242	502.96															C												
904-243	519.96															C												
904-244	760.96																			C		D			D			
904-245	209.96																											
904-246	214.94															C												
904-247	519.94																											
904-248	502.96																				D							
904-249	519.96																											
904-250	753.96																											
904-251	760.96																											
904-252	709.96									D																		
904-253	209.98																											
904-254	519.94																											
904-255	519.94																											
904-256	214.98																											
904-257	502.94																											
904-258	14.98																											
904-259	99.96																											